ALFRED ELECTRONICS 897 COMMERCIAL STREET, PALO ALTO, CALIF.

MICROWAVE OSCILLATOR
620 SERIES

Serial No. 146

TABLE OF CONTENTS

Page No.

Specifications

Section 1 GENERAL

1-1 Description 1

Section 2 THEORY OF OPERATION

2-1 General 3
2-2 Backward Wave Oscillator Tube 3
2-3 Helix Supply 6
2-4 Sweep Generator 6
2-5 Schmitt Trigger 11
2-6 Sweep Out 12
2-7 Blanking Pulse 12
2-8 Non-Linear PowerAmplifier 12
2-9 Helix Overcurrent Relay 15
2-10 Collector Supply 15
2-11 Anode Supply 15
2-12 Retrace Control 15
2-13 Amplitude Modulation 16
2-14 Markers 16
2-15 Power Supplies 17
2-16 Power and Switching 19

Section 3 INSTALLATION AND OPERATION

3-1 Transit Damage 21
3-2 Power Input 21
3-3 Mounting 21
3-4 Operating Controls 21
3-5 Panel Connectors 24
3-6 Setting-Up Procedure 25
3-7 Typical Set-Ups 27

Section 4 MAINTENANCE

4-1 General 29
4-2 Preventive Maintenance 29
4-3 Trouble Shooting 30
4-4 BWO Electrode Voltage Measurement 32
4-5 Chassis Disassembly Procedure 33
4-6 BWO Tube Replacement 33
4-7 BWO Tube Alignment 34
4-8 Internal Adjustments 36
4-9 Dial Assembly Repair 38
4-10 Calibration of Markers 41
4-11 Blower Replacement 42
4-12 Coaxial RF Connector 42
4-13 Warranty 43
4-14 DC Voltage Checks 43

MICROWAVE OSCILLATOR
MODEL 623

SPECIFICATIONS

Frequency Range:	4.0 to 8.0 kmc/s. Continuously adjustable with direct calibrated dial, 1% accuracy.
Power Output:	10 mw minimum Continuously adjustable from zero to maximum. RF may be selected on or off during sweep retrace.
Residual AM:	40 db below CW level.
Residual FM:	Less than ± .002% peak of lowest frequency.
Drift:	± .025% per hour after warmup in $\pm 5^{\circ}$ C ambient change.
Frequency Markers:	Two markers continuously adjustable over entire frequency range on calibrated dial, 1% accuracy. Width: 0.5% of total range. Negative pulse, adjustable 0 to 5 volts. Panel BNC connector.
RF Connector:	Type N female
VSWR:	2.5:1 maximum
Sweep	
Selector:	Recurrent Sweep, Single Sweep, CW, or External.
Width:	Continuously adjustable from 0 to any part of the entire frequency range. Sweep deviation starts from CW value and increases frequency.
Time:	100 to .01 seconds, selected with panel switch for 10, 1, or .1 seconds, and X1 to X10 continuous vernier multiplier control.
Control:	Single Sweep triggered by either, Panel "start" button External positive going signal 20 volts or greater Internal line frequency signal.
Monitor Output:	Sweep Out, positive linear sawtooth, 45 volts peak. Blanking Out, 75 volts negative during flyback. Panel BNC connector.
External:	200 volts gives full sweep width. Negative voltage increases frequency from CW value. DC to approximately 10 kc response. Input Impedance, 2 megohms shunted by approximately 40 mmfd. Panel BNC connector.

Amplitude Modulation

Selector:	CW, Square Wave or External.
Internal Square Wave:	RF output is alternately 0 and unmodulated CW value. Frequency 800 to 1200 cps, set by panel control. Rise and fall time less than 1 microsecond symmetry within 5%.
External:	-25 volts signal increases RF output from 0 to maximum. Internal 0 to 25 volt bias adds to signal. Rise and fall time, .5 microseconds maximum. DC to approximately 1 mc response. Input impedance, 100 K shunted by approximately 40 mmfd. Panel BNC connector.
Metering:	Helix or Collector current, 2" meter.
Protection:	Resistors connected across all high voltage capacitors to assure discharge upon removal of power. Helix overcurrent relay turns off BWO tube electrode voltages if safe helix current is exceeded.
Fusing:	Separate fuses for Solenoid, Low and High Voltage supplies.
Switching:	Separate Power and RF on-off switches.
Power Input:	105 to 125 volts, 60 cps, approximately 850 VA.
Physical:	Bench or standard 19" rack. Removable handle sides permit rack installation. Height: 15 3/4" Width: 19" Depth: 15 1/2" behind panel, 17" overall.
Finish:	Panel grey hammertone. Sides and top, dark metallic grey.
Weight:	105 pounds.

SECTION 1 - GENERAL

1-1 DESCRIPTION

The ALFRED 620 series Microwave Oscillator is a compact, general purpose wide band signal source. Utilizing a voltage tuned Backward Wave Oscillator tube and low drift precisely regulated power supplies, it provides either a single, stable frequency, manually adjustable to any value in the range, or electronically scanned frequencies over all or any part of the band. The output frequency may be varied in proportion to an external voltage, or linearly with time over intervals from .01 to 100 seconds by an internal sawtooth generator. The internal sweep may be single or recurrent. Single sweep may be triggered by panel push button, external signal, or an internal power line frequency source.

For X-axis drive of oscilloscopes or recorders, a positive going sweep voltage proportional to frequency during the electronic sweep is provided on a panel connector. Peak voltage is 45 volts. During flyback interval a negative pulse of approximately 75 volts is also brought out for oscilloscope blanking or pen control on recorders. An internal switch selects RF "on" or "off" during sweep flyback. Normally it is set in OFF position so RF level is zero during retrace.

Two electronically generated frequency markers are provided. These are short triangular negative pulses which may be summed into any presentation for calibration purposes. Marker width is 0.5% of total frequency range and amplitude is adjustable from 0 to 5 volts. A large direct reading slide rule dial calibrated within ±1%, provides instantaneous frequency presentation of markers, CW or sweep start, and sweep end.

The RF signal from the oscillator may be selected by a panel switch to be CW, or amplitude modulated by either an internal 800 to 1200 cps square wave generator or an external signal. External response is DC to about 1 mc making possible pulse rise and fall times of .5 microseconds or less. Frequency variation from amplitude changes is held extremely low by taking advantage of the compensation which occurs when modulation is applied to the BWO cathode.

A panel meter monitors Oscillator tube currents during normal operation or adjustment. The Backward Wave Oscillator tube requires no RF adjustment, is encapsulated for protection, and is easily replaced. Protective circuits prevent damage to the BWO tube during alignment or from most component failures.

The instrument is supplied normally, with sheet metal sides having handles, making it suitable for semi-portable or bench use. However, simply by removing the sides the instrument may be rack mounted.

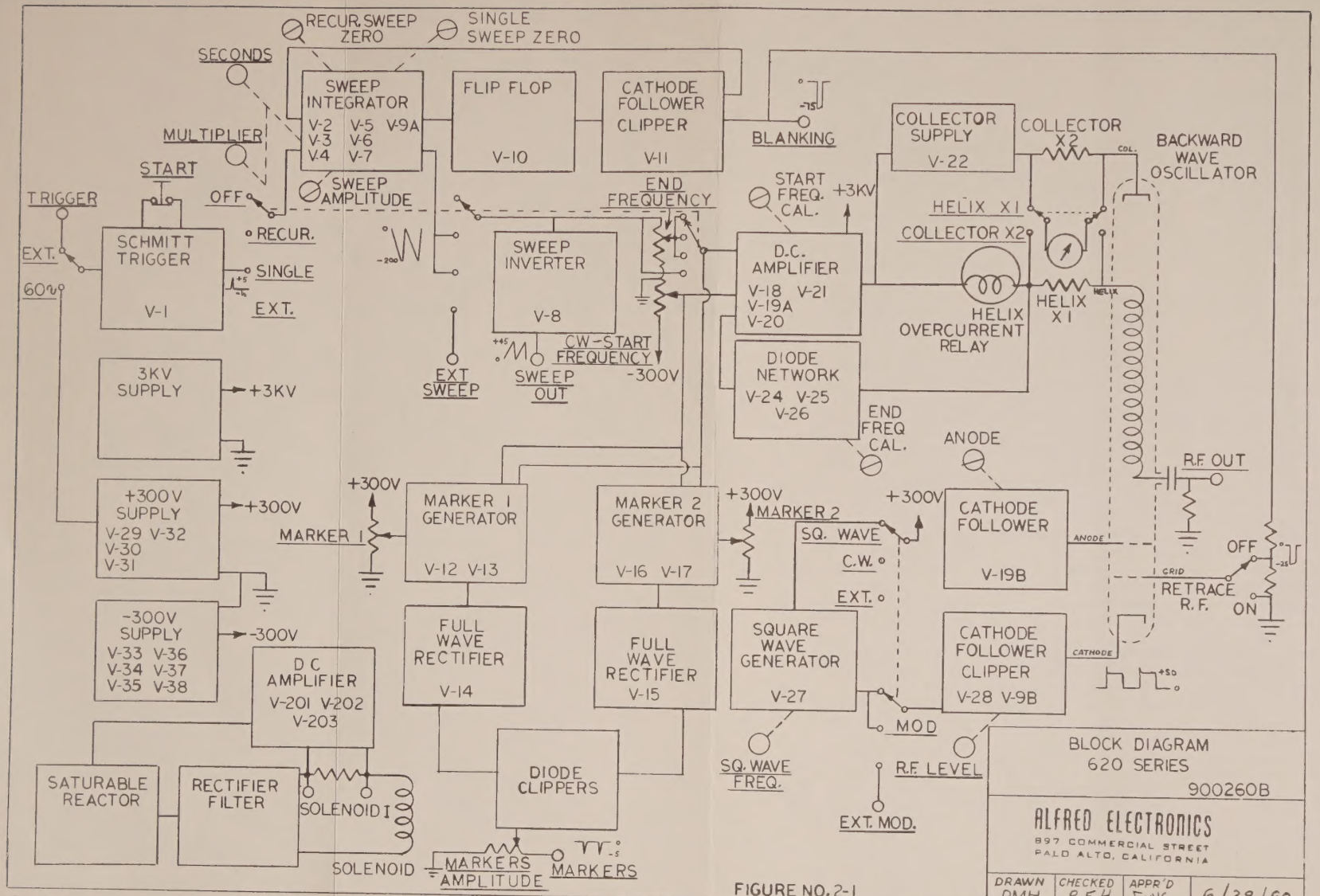


FIGURE NO. 2-1

BLOCK DIAGRAM
620 SERIES
900260B

ALFRED ELECTRONICS
897 COMMERCIAL STREET
PALO ALTO, CALIFORNIA

DRAWN	CHECKED	APPR'D	
PMH	R.F.H.	FWC	6/29/60

SECTION 2 - THEORY OF OPERATION

2-1 GENERAL

The Model 620 series Microwave Oscillator consists essentially of a Backward Wave Oscillator tube which produces the high frequency output and a group of extremely stable versatile sources to operate the tube and its focusing electromagnet. A block diagram for the instrument is presented in Figure 2-1.

2-2 THE BACKWARD WAVE OSCILLATOR TUBE

Since the radio frequency signal from the instrument is generated by the Backward Wave Oscillator tube, an understanding of its characteristics will help clarify the purpose and function of the various circuits. The BWO tube contains an electron gun which produces and forms an electron beam that travels axially through a long slender coil or helix to a metal collector electrode as indicated in Figure 2-2. Surrounding the tube is an electromagnet which produces a strong axial field. The diameter of the beam is carefully determined by cathode size and focusing electrodes so that with the aid of a magnetic field most electrons may pass very close to, but do not contact the helix inside surfaces. To assure arrival of the beam at the collector the tube is mechanically positioned so the helix and magnetic field axes are parallel.

Interaction of fields in the electron stream and the helix is such that a minor disturbance will start RF oscillations. A wave develops on the helix which increases in amplitude from the collector to the gun end. The electron beam is bunched by the fields from this wave and thereby provides increased energy or effective gain in the direction of flow from the gun toward the collector end of the tube.

In simplified terms the RF field on a given turn of the helix, velocity modulates the electrons so that upon arrival of the electrons at the next turn, some bunching has taken place. The beam returns RF energy to this second turn which upon receipt will travel back along the helix towards the gun to the earlier turn. The original bunching power in the first turn is thus replaced and the process continues, provided the total phase delay in the beam and helix is correct for positive feedback. Actually this interaction and feedback is continuously distributed all along the beam and the helix.

Since the phase on the helix varies with the frequency, the frequency at which oscillations are sustained automatically becomes that which gives correct phase. By changing the velocity of the electrons, the time delay or phase shift in the beam is altered and thus the total loop phase is changed. The frequency therefore readjusts itself so that the new helix phase just corrects for the change in beam phase. Electron velocity is controlled by the accelerating potential, namely, the helix to cathode voltage. Thus the output frequency is determined by the helix voltage which is operated in the range of 225 to 2300 volts positive with respect to the cathode.

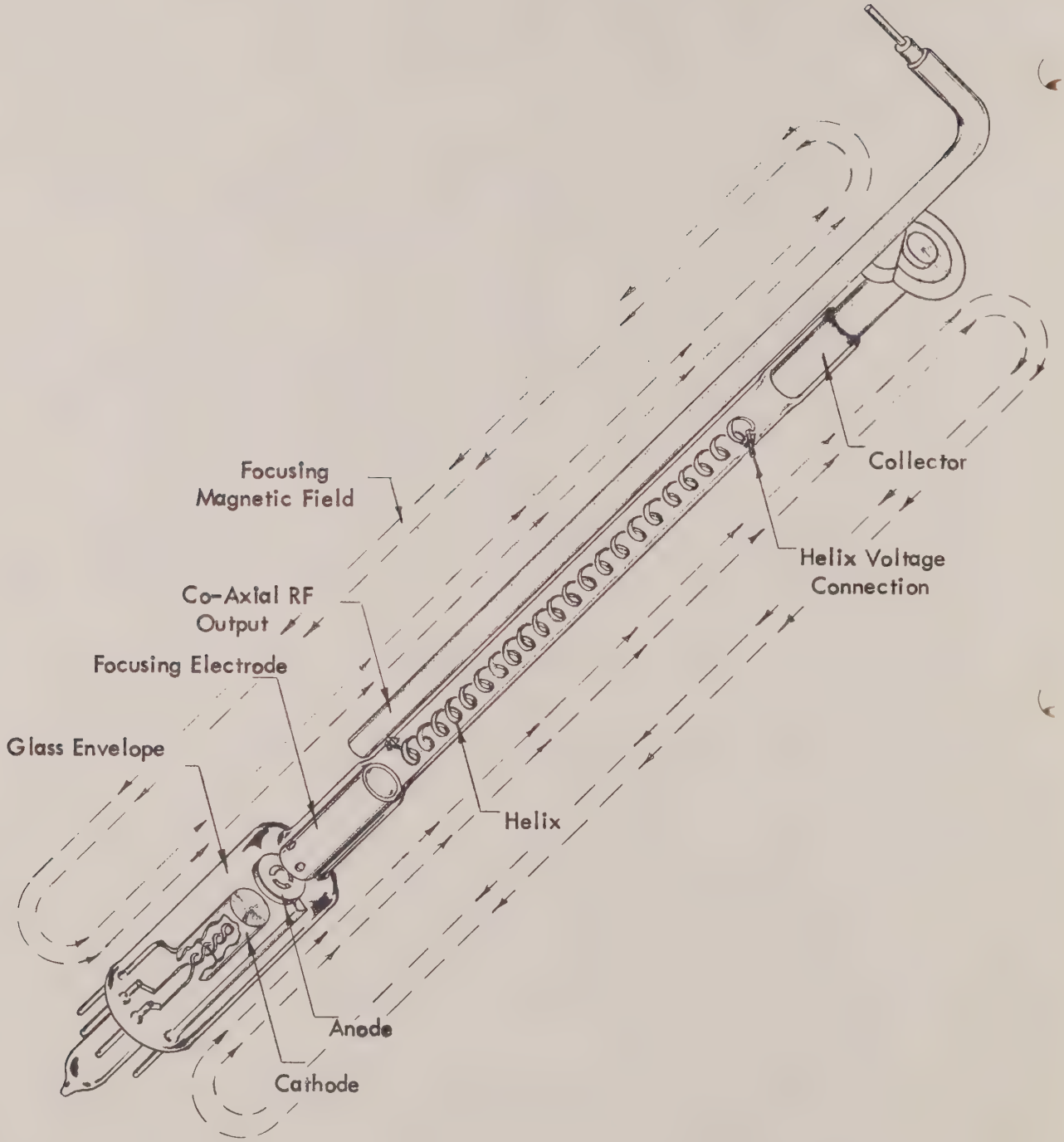
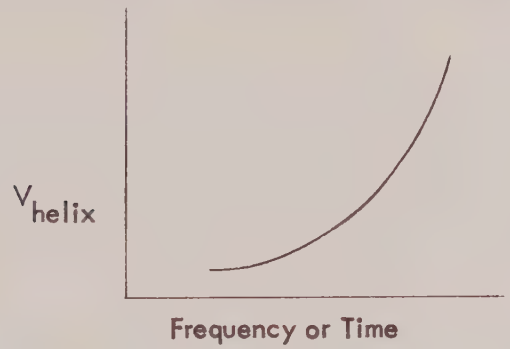


Figure 2-2
Backward Wave Oscillator Tube

The oscillator frequency increases with helix voltage very closely to a logarithmic relation as indicated in Figure 2-3 . Thus to obtain a linear frequency variation, helix voltage must vary exponentially.



$V_{helix} \approx K_1 e^{K_2 F}$

$F \approx K_3 \log_e V_{helix}$

K_1, K_2, K_3, constants of the BWO tube.

Figure 2-3

The collector electrode receives the beam after it leaves the helix and is operated approximately 100 volts above the helix potential so that any secondary electrons produced return to the collector. If they were to drift back into the helix area the slight change in beam density would affect frequency and helix current would not be a true measure of the forward electron interception.

Other factors which affect frequency, but by much smaller amounts, are the magnetic field, slight mechanical deformation of the helix structure, temperature changes in the magnet winding, and beam current density. A current regulated source with low ripple for the focusing magnet reduces frequency errors from magnetic field changes to less than .001%. A large capacity blower holds temperature rise of the solenoid and BWO tube to less than 30° C which makes negligible any frequency drift from thermal changes.

The electron gun contains a heated cathode and two aperature disc type control electrodes which help to form the beam and also control beam density. The disc nearest the cathode is termed the grid and the other more remote electrode is called the anode. Their influence on the beam current is very similar to that of the control and screen grids respectively in a conventional tetrode. The RF output from the BWO tube is proportional to beam current. Normal beam current and hence rated RF output results with the grid at 0 volts and the anode about +200 volts, both relative to cathode. Reducing the grid to -25 volts or the anode to 0 will cut off the beam and RF output. Turning the beam from off to on very rapidly by applying a voltage to either the grid or anode, will cause the RF oscillations to build up almost exponentially with a time constant of $\frac{Q}{\pi f}$, where Q is the tuned circuit figure of merit. For stable operation, the Q of the BWO tube should be as high as possible. In practice it is approximately 1000. Thus if RF envelope rise time is defined as 4 time constants, at 3 kmc/s rise time

is equal to $\frac{4Q}{\pi f} = \frac{4 \times 10^3}{\pi \times 3 \times 10^9} \approx$ .4 microseconds. By proper design, the pulsed rise and fall times of BWO tubes used in Series 620 Oscillators is held to less than .5 microseconds.

Power level change per volt of grid or anode voltage is greatest at the high end of the frequency range. This results primarily from the non-intercepting hole in the disc design of the grid and anode electrodes. The electric fields from the discs have the greatest influence on the outer electrons of the beam. In the helix region the RF fields penetrate only the outer portions of the beam at the high end of the band. Therefore, as the anode or grid voltage is made more negative the outer portion of the beam is cut off first, removing the electrons which interact with the RF fields at the high end of the band. Since RF field penetration is greater at lower frequencies the remaining inner electrons will still produce enough interactions for oscillations until beam is completely cut off. Because of the variation of control sensitivity with frequency, either anode or grid control will cause the high end of the band to go to zero first.

2-3 HELIX SUPPLY

The helix supply consists of two major portions, a Sweep Generator followed by a non-linear Power Amplifier. The sweep generator produces an extremely linear sawtooth voltage of accurately controlled time and amplitude. The power amplifier is an extremely stable non-linear DC feedback amplifier.

A linearly varying voltage applied to the amplifier input, gives approximately an exponential output, which in turn is applied to the helix of the BWO tube to produce a linearly varying frequency. For manual frequency control, the input voltage is obtained from a linear 10 turn potentiometer across a stable DC supply, so frequency is exactly proportional to shaft rotation. In like manner the sawtooth voltage is also connected to a 10 turn linear potentiometer. By summing the DC and sawtooth voltages from the potentiometers, the frequency will sweep from the manually set value, over a range determined by the amplitude of the sawtooth voltage.

2-4 SWEEP GENERATOR

In the following text front panel control titles are capitalized and underlined while chassis controls are indicated by capital letters only.

Refer to Figure 4-2 for the circuitry involved in the sweep generator section of the instrument. In essence, the sweep generator is a reasonably high gain DC amplifier with capacitive feedback and a rectangular wave input. Such an amplifier may be represented symbolically as shown in Figure 2-4.

The amplifier A is adjusted for zero output with zero input. Due to the high gain of A, any input E_1 will cause the feedback current through C to be of a magnitude and direction to cancel the input current I_1. This self balancing action tends to keep the input of A at zero volts. The charging current through C therefore is

equal to $\frac{E_1}{R}$ a constant, I_2 therefore also is constant. The voltage across C becomes $\frac{I_2}{C} = \frac{E_1 t}{RC}$. Since the input to A tends to remain at zero, the output E_o is equal to the voltage across C or $\frac{E_1 t}{RC}$, a constant multiplied by time t. Thus a linearly changing output voltage is obtained. The slope of the output wave can be varied by changing E_1, R or C.

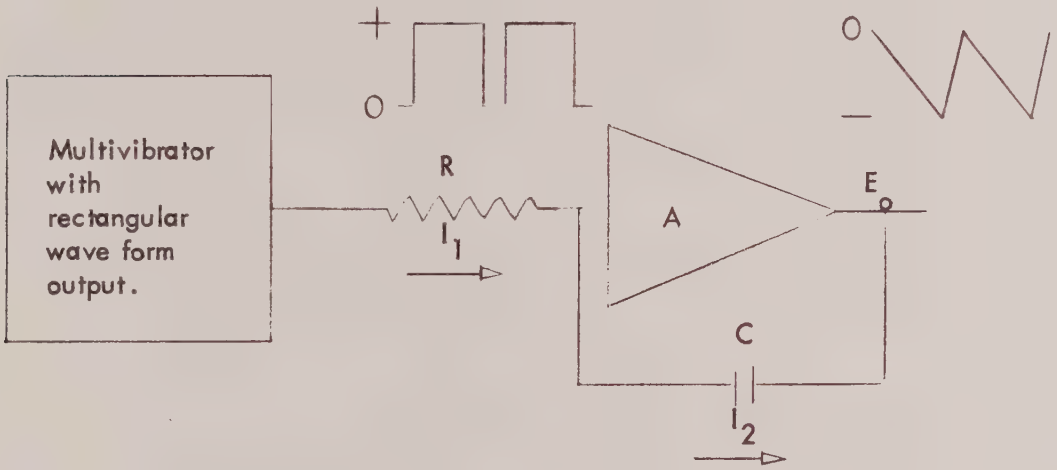


Figure 2-4

In the actual circuit R is obtained from the resistor network of R9 through R13; C is selected by the SWEEP SECONDS switch SW3; the rectangular wave input (SW4 on RECUR) is from the multivibrator circuit of V10 and its associated components. The amplifier is composed of tubes V2, V3, V4, V5, V6 and V9. The output E_o is taken at pin 2 of VR tube V6, and the input to the amplifier is made at the grid of V2A, pin 7.

In the amplifier, tube V2 is connected differentially to minimize drift. Tube V3B is connected as a cathode follower. VR tubes V4, V5 and V6 maintain the cathode of V3B at a fixed voltage of approximately 258 volts above the output voltage E_o. This constant drop is used to determine the start and end voltage levels of the sweep. Tube V9A maintains essentially constant current through the cathode follower V3B and the regulator tubes V4, V5 and V6. To do this, the grid voltage of V9A is fixed and cathode is self biased with resistor R21. The change in grid bias to hold the plate current constant for a plate voltage swing of 200 volts is only about 4 volts. The change in voltage across R21 therefore is small, making the V9A plate current nearly constant.

The bi-stable multivibrator V10 produces a rectangular wave output. Plate pin 1, of V10B is connected to cathode follower V11A to provide a rectangular wave input to the amplifier through diode V3A. This produces the linearly varying sawtooth output. The external signals required to switch the multivibrator are derived from the sweep voltage levels and determine the start and end of each sweep.

To understand the interaction between the multivibrator and amplifier, assume that the SWEEP switch SW4 is in the RECUR position, that a retrace has just been completed, and a forward sweep is just starting. At this instant the multivibrator has just switched and the following conditions exist. V10A has just received a positive input and is conducting heavily, V10B is cut off with its plate at +258 volts causing cathode follower V11A to conduct heavily, setting its output to +40 volts. This +40 volts has just cut V3A off, removing a negative input to the amplifier. A positive 200 volts through the network of R9, R10 and R11 now drives the amplifier during the forward sweep. The positive input causes amplifier V2A plate, pin 6 to proceed linearly downward from approximately +258 volts. Cathode of V3B follows with the same waveform and level.

The output E_o follows the cathode of V3B at a constant 258 volts more negative, producing the capacitor feedback current I_2 which balances the positive constant input current I_1 to maintain the input grid of V2A at a zero level.

The output voltage will continue to decrease linearly until the input to R13 is changed. This change is brought about by the action of diode V7A. V10B is cut off, the top of R23 is at +258 volts, and the slider of R24 is adjusted to about +58 volts in the divider network circuit of R23, R24, R25 and R36. When the cathode of V3B decreases from 258 volts to the value set by the slider of R24, V7A will conduct. Since VR tubes V4, V5 and V6 hold E_o to exactly 258 volts below the cathode of V3B, the point at which V7A conducts establishes the end value of the forward sweep, namely, -200 volts. When V7A conducts, the increase in current in R23 drops the grid bias of V10A from about 0 to -1 or -2 volts. V10A plate voltage increases and V10B plate voltage decreases due to the feedback from V10A. As V10B plate decreases, the feedback of V10A grid causes further increase in V10A plate voltage. This feedback action between the two tubes continues until the multivibrator is completely switched. The switching action is almost instantaneous.

Cathode follower V11A follows the plate of V10B so that its output also quickly switches, from about +40 to a -66 volts. Thus a step function of -66 volts is applied to R13 from a low impedance source V11A through diode V3A. This negative step input to V2A reverses the output voltage at precisely -200 volts.

The output voltage E_o will continue linearly in a positive direction during the retrace interval until the input at R13 again becomes positive. The end of retrace is controlled by diode V7B. At the start of the retrace, the plate of V10B is down to about +75 volts and there is a large bias of -85 volts on V10A

grid from the divider network of R23, R24, R25 and R36. The plate of V7B is at E_o and the cathode is tied to V10A grid. As E_o increases towards zero, it will reach a value where V7B conducts. The grid voltage on V10A is now controlled by E_o through V7B. RECUR SW ZERO potentiometer R18 is adjusted so that when E_o reaches exactly zero volts, V7B will put a bias on V10A of such value that V10A starts to conduct. This will start the reversing action in the multivibrator and change the output of the cathode follower V11A from -66 volts back to the +40 volts. The switch from -66 volts to +40 volts cuts V3A off and a positive step input to the amplifier is again applied.

When the SWEEP switch SW4 is placed on SINGLE position, single sweep operation is obtained. The sweep circuit action is the same as in the RECUR mode but the initiation or start of a forward sweep is now controlled by a pulse from the Schmitt trigger circuit instead of being derived from the output E_o. SWEEP switch SW4 disconnects the plate of V7B from the plate of V9A, and connects it to the output of the Schmitt trigger circuit. At the same time the output, E_o, is connected to the input grid of V2A through diode V7C. With these connections, V7B now controls the start of the sweep instead of the zero level as it did in the RECUR mode, and V7C controls the zero level point between sweeps. The action of V7A in reversing the forward sweep at -200 volts is the same as for RECUR mode.

When the retrace portion of the sweep reaches zero volts, V7C will conduct. No further rise can occur since all of the output, E_o is now coupled back to the grid of V2A through the low conducting impedance of V7C. The amplifier gain is thus reduced to approximately zero. V7C can be made to conduct with its plate and E_o at precisely zero volts by adjustment of SINGLE SW ZERO potentiometer R17. This will change the bias on V2A until it is a negative value exactly equal to the drop across V7C. The output, E_o, will remain at zero volts as long as there is a negative input voltage to the amplifier at R13 and this condition will exist until the multivibrator is made to reverse. The left side of multivibrator V10 is cut off with its grid held to a small negative value set by the -10 volts from the junction of R7 and R8 acting through diode V7B. Thus, the multivibrator is now receptive only to a positive pulse. A positive signal from the Schmitt trigger is transmitted by V7B to the grid of V10 left side to reverse the multivibrator. This reversal changes the input to the sweep amplifier from negative to positive and a forward sweep is started. During the forward sweep interval, any subsequent positive trigger will have no effect since the left side of multivibrator V10 is now conducting heavily. Any negative trigger would not be transmitted by V7B. When the forward sweep reaches -200 volts, diode V7A conducts and puts a negative going signal on the grid of V10 left side which reverses the multivibrator and starts the retrace interval. The multivibrator left side is now cut off with

its grid voltage again established by the negative voltage at the junction of R7 and R8. Any subsequent negative signals would have no effect but any positive pulse received before the retrace is completed would cause the multivibrator to initiate the forward sweep before the retrace interval is completed. To prevent a positive pulse from starting another sweep during the retrace interval, the total sweep interval should be less than the period of the triggering waveform. In general, since maximum retrace time is about 18 percent of total sweep period, SWEEP SECONDS and MULTIPLIER may be set for sweep periods up to four times trigger period and satisfactory sweeps will occur. Thus, for 60 cycle triggering, SWEEP SECONDS should always be on .01 position and SWEEP MULTIPLIER adjusted for less than X6.7.

A single positive pulse can be applied to the input of the multivibrator to secure a single sweep by placing TRIGGER switch SW1 on EXT and pressing START switch SW2. Also, the sweep may be initiated by an external voltage source connected to TRIGGER jack S4 with TRIGGER switch SW1 placed on EXT position.

The sweep time is a function of the slope of the output wave shape since the output voltage levels are fixed at zero and -200 volts. Slope can be varied by changing input voltage E_1, R or C. C is changed in decade amounts by SWEEP SECONDS switch SW3 and R is varied by MULTIPLIER potentiometer R12. To make the retrace time less than the forward sweep time, R is made appropriately smaller. The shortest practical value of retrace time is limited by the characteristics of the BWO tube to about 1.8 milliseconds. Thus when SWEEP SECONDS switch SW3 is on the .01 seconds position and R12 is at X1 (minimum) position, the total sweep is 10 ms and the forward portion of the total sweep is 8.2 ms. Network R9, R10, R11 gives an equivalent input voltage of +200 volts with R for 8.2 ms forward sweep. For a 1.8 ms retrace time with an input E_1 of 66 volts the time constant RC must be reduced to about 1/14 of its forward value. Since C is fixed, R must be changed. This is done by inserting the input from the low impedance cathode follower, into the amplifier at R13; thereby shunting the R9, R10, R11, and R12 and reducing the total effective R.

The MULTIPLIER R12, in its maximum resistance position increases the forward sweep time by approximately a factor of 10. It has no effect on the retrace sweep time, so that the percent of total time taken by the retrace is progressively smaller as R12 is increased. The proportion of retrace to forward trace remains the same when the sweep time is changed by SWEEP SECONDS switch SW3.

When SWEEP switch SW4 is on the OFF position, the sweep output E_o is shorted to the input of V2A thus reducing the output E_o to zero. The switch in this position also grounds the input to the non-linear power amplifier.

When SWEEP switch SW4 is in the EXT position the linear sweep circuit is deactivated in the same manner as in the OFF position except the sweep input of the non-linear power amplifier is made to EXT SWEEP jack S5, to permit application of external sweep voltages.

2-5 SCHMITT TRIGGER

Refer to Figure 4-3 for the Schmitt trigger circuitry.

Any arbitrary positive going waveform of 20 volts or more will operate the Schmitt trigger to produce a pulse at junction of R7 and R8. A positive pulse from the trigger is used as the input to the grid, pin 7, of the multivibrator tube V10 through diode V7B to initiate a sweep. When TRIGGER switch SW1 is on EXT a trigger may be initiated either by a positive input of approximately 20 volts at TRIGGER connector S4, or by depressing START switch SW2. A 60 cycle pulse is obtained by placing TRIGGER switch SW1 on 60 ∿.

With TRIGGER switch SW1 on EXT, the right side of V1 is conducting relatively heavy, producing a cathode voltage of about 15 volts on R6 to cut off the left side of V1. The right side, plate pin 6, is at about 50 volts. The voltage at the junction of R7 and R8 is about -10 volts and capacitors C3 and C4 are thus charged to 60 volts. When the START switch SW2 is depressed, V1 right side is immediately cut off and the capacitors will now charge to 310 volts. Since the voltage across the capacitors cannot change instantaneously the 250 volt change will appear across resistors R3 and R7. The portion of this change at the junction of R7 and R8 is determined by the proportionate size of R7 to R3 and is such that an approximately 9 volt pulse is obtained when there is no output load on the trigger. The pulse has a sharp, triangular shape determined by the short time constant of the charging circuit.

When the trigger output is used to control the sweep circuit by placing SWEEP switch SW4 in the SINGLE position, the effective charging resistance is lowered when V10 left side conducts, due to the shunting effect of the diode resistance of V7B and V10 left side, grid to cathode, across R7. This reduction in the effective value of R7 reduces the positive portion of the pulse to about 2 volts.

When switch SW2 is released, V1B will again conduct and the action will reverse, producing a negative pulse of about -25 volts.

A positive pulse can also be generated by a positive input of about 20 volts at TRIGGER input connector S4 with TRIGGER switch SW1 on EXT. This causes V1 left side to conduct. The voltage drop across R4 causes V1 right side to conduct less which decreases the cathode voltage at R6 to cause V1 left side to conduct still more. This positive feedback process continues so that the accumulative action is such as to turn V1 left side full on and V1 right side off almost instantaneously to produce a positive output in the same manner as when START switch SW2 is depressed.

When TRIGGER switch SW1 is on 60 ∼ , an internal 60 cycle voltage of approximately 28 volts peak is applied to the input of the trigger circuit. When the input reaches a value sufficient to turn V1A on, a positive pulse is generated at the trigger circuit output. The output returns to the -10 volt condition and stays there until the input to V1 left side decreases to the point where current in V1 left side starts to decrease. The decrease in current in V1 left side initiates a reversal in the trigger circuit and a negative pulse appears at the output junction of R7 and R8. The circuit always reverts to the -10 volt condition and produces a positive pulse each time V1 right side is cut off and a negative pulse each time it is turned on.

Since a positive pulse to the multivibrator during the retrace interval would initiate a sweep and thereby cut the retrace interval short, care must be taken when controlling the sweep by means of the Schmitt trigger circuit that the periods of the sweepand the triggering waveform are such that a positive pulse does not occur during the retrace interval. If the sweep period is made less than the period of the triggering waveform, no interference can occur, however, in practice, satisfactory sweep action may be obtained for sweep periods up to 4 times the triggering period. Thus, for 60 cps triggering, SWEEP SECONDS switch must be on the .01 (10 ms) position since the next lowest position .1 (100 ms) is 6 times greater than the 16.7 ms period of the trigger. In like manner, MULTIPLIER potentiometer R12 may be set up to a maximum of 6.7 with SWEEP SECONDS switch on .01 position for 60 cps triggering.

2-6 SWEEP OUT

The internal sweep waveform is inverted, reduced in amplitude, and brought out as a positive sawtooth at the panel SWEEP OUT connector. The sweep sawtooth is applied through R73 to the grid of amplifier tube V8. Negative feedback through R75 determines gain of the amplifier so output is approximately 45 volts peak. The two halves of V8 are connected differentially to minimize drift.

2-7 BLANKING PULSE

A voltage of -80 volts appears at jack S7 during sweep retrace or between single sweeps. This voltage is obtained from the junction of R31, R33 and R34 at the output of cathode follower V11A. V11B is connected as a shunt diode clipper to hold it at zero level during the sweep interval.

2-8 NON-LINEAR POWER AMPLIFIER

A linearly varying voltage applied to the input of the non-linear power amplifier produces an exponentially varying output voltage. When this output is applied to the helix of the backward wave oscillator tube, the RF frequency changes linearly. See Figure 4-4 for the circuitry of the non-linear amplifier portion of the instrument.

The non-linear amplifier is a high gain DC amplifier with negative feedback and may be represented as shown in Figure 2-5.

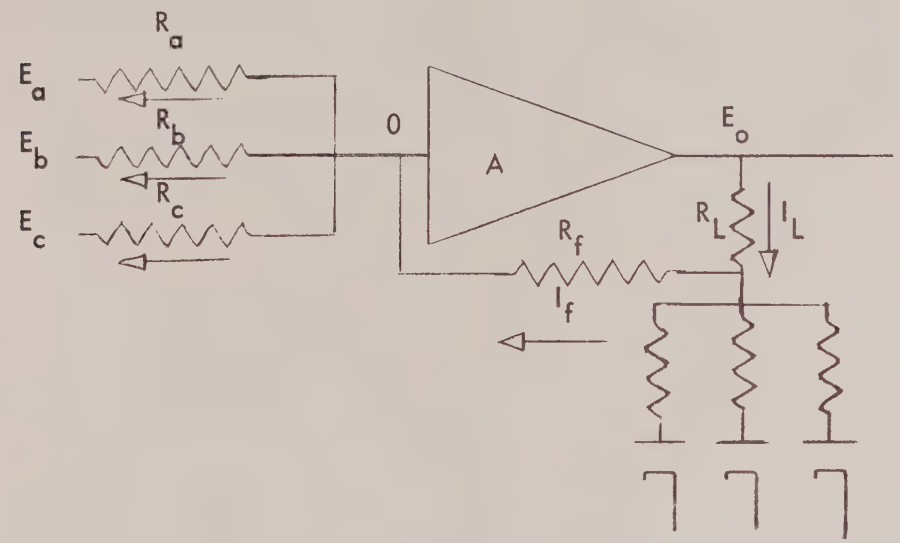


Figure 2-5

Input E_a is a selected input voltage from the panel CW-START FREQUENCY potentiometer R35. E_b is the linearly varying sweep voltage from the sweep circuit with amplitude adjusted by the panel END FREQUENCY potentiometer R37. E_c is preset voltage determined by START FREQ CALIB potentiometer R104.

The self-balancing action of the amplifier will provide an output E_o of such a magnitude that the feedback current I_f is equal and opposite to the sum of the currents produced by E_a, E_b, and E_c through resistors R_a, R_b, and R_c.

E_o is made an exponential function of the input by progressively shunting the feedback circuit with a series of diodes that are biased to conduct consecutively with increasing E_o. Since the feedback current I_f must balance the sum of the input currents, the output voltage E_o must increase to supply both I_f and the increment currents required by the diodes. By controlling the conduction currents of the diodes with the plate resistors R107 through R115, the proper increments in slope of E_o can be obtained. Diode bias is provided by divider resistors R116 through R126.

R_a is the resistor string R39A through R44, R_b is the resistor string R39B and R45 through R49, R_c is R103 and R104, R_f is feedback resistor R106 and R_L is resistor string R169-R175. The diodes are V24, V25 and V26 which have three diodes in each envelope.

The amplifier A is composed essentially of tubes V18, V19, V20, V21, V22 and V23 with their associated circuitry. V18A is connected to V19A to form a differential amplifier. The grid of V18A is the amplifier input and the grid of V19A is connected to ground as reference. Connected in this manner, only the difference between the input at grid of V18A and the input at grid of V19A

(which in this case is at ground potential) is amplified, to produce a push-pull output at the plates. Any drift in level, due to heater voltage variation for example, is minimized by the differential amplifier. To utilize both outputs of the differential amplifier in driving amplifier tube V20, the output from the plate of V19A is connected directly to the grid of V20 and the other output is connected to the cathode through cathode follower V18B. By employing V18B as a cathode follower, the load for V18A is a high impedance grid, the same as V19A. At the same time both proper polarity and load for cathode input to V20 is also obtained. Except for a slight loss in gain of the output from plate of V18A through cathode follower V18B, the full linearly varying push-pull output of the differential amplifier is effectively applied to grid and cathode of amplifier V20. The plate output of V20 is used to drive tube V21.

Tube V21 is a cathode follower which provides voltage in the range of 225 to 2300 volts through the overcurrent relay RY3 to the helix of the BWO tube. Grid control of V21 is from the plate of V20 through load resistor R62. The screen grid supply for V21 is obtained by charging C17 through rectifier SR13 and is regulated to +108 volts by VR tube V22. The sum of the constant screen grid voltage and the varying cathode voltage of V21 is the plate supply for V20. The grid swing on V21 required to produce the wide output voltage range is small. Since the voltage across R62 is only the sum of the constant screen voltage and V21 grid swing the current variation in R62 is small. A pentode is used for V20 to permit a wide voltage swing with a small current variation.

The complete amplifier action is briefly summarized as follows: The summed input, which may be either a fixed or varying voltage, is differentially amplified to provide a push-pull input to V20. The plate variation in V20 is used as the grid input to cathode follower V21. The output voltage of V21 moves up or down as required to furnish both the balancing feedback current to the input and the diode shunting current. The output E_o is made exponentially proportional to the input by controlling the diode currents.

With E_a and E_b set to zero and E_c properly adjusted with START FREQ CALIB potentiometer R104, the output E_o of the amplifier provides the helix of the BWO with the exact voltage required at the lowest frequency. Depending upon the BWO tube the voltage may be 225 to 550 volts at this point. When sawtooth voltage E_b is zero, the output frequency will be determined by E_a, as obtained from the setting of CW-START FREQUENCY potentiometer R35. By applying the linear sweep voltage E_b from END FREQUENCY potentiometer R37, the instrument will produce a linearly varying frequency, sweeping the range from the start value as set by R35 to the end frequency as set by R37.

The CW-START FREQUENCY potentiometer R35 and the END FREQUENCY potentiometer R37 are mechanically connected so that the sum of the voltages can never exceed the value required for maximum frequency output of the instrument. It is also noted that the potentiometers are mechanically linked so that the end frequency setting may not be less than the start frequency setting.

2-9 HELIX OVERCURRENT RELAY

The maximum safe value of BWO tube helix current is about 3 ma. To provide protection with a safety margin, overcurrent relay RY3 is employed to trip at approximately 2 ma. It has a resistance of 10 K and requires 2 ma to trip. Compensation for the current in resistor string R169-R175 is provided by shunting the relay winding with R63. The current in R169-R175 varies from about .2 to .9 ma over output voltage range. The helix current at trip therefore varies from about 2.7 ma at the low voltage to about 2.0 ma at the high end.

When relay RY3 trips it energizes relay RY2 which in turn releases relay RY1. Opening relay RY1 contacts, disconnects the primary input to high voltage power transformer T1 and the +300 plate voltage supply to V18A and V19B. V18A is cut off to prevent its overloading when high voltage is removed from V20. V19B is cut off to remove anode voltage from the BWO tube.

Meter M1 is a 0-1 ma milliammeter. Shunt R68 is used to change the meter scale to required range when measuring helix current and shunt R66 is used when measuring collector current. The meter switch position may be changed during operation without danger from transient effects since the shunts remain connected to the load during the switching action.

Neon tube V23 protects capacitor C16 against an abnormal voltage such as might occur if RY3 coil circuit should open.

2-10 COLLECTOR SUPPLY

The collector voltage to the BWO collector electrode is maintained at essentially a constant value above helix voltage. This is accomplished by using the +108 volt screen grid supply of V21 consisting of C17, rectifier SR13 and VR tube V22. The voltage from BWO helix to collector is thus the constant +108 volts across V22 plus the small drop in the helix overcurrent relay.

2-11 ANODE SUPPLY

V19B is a cathode follower with adjustable grid voltage from potentiometer R176 to provide a fixed source of positive voltage from about 25 to 300 volts for the BWO tube anode. The plate and grid voltage for V19B is supplied through relay RY1 and is disconnected when RF power is removed.

2-12 RETRACE CONTROL

With RETRACE switch SW10 in the OFF position, the negative blanking

voltage is attenuated by R127 and R128 to -27 volts and is applied to the grid of the BWO during the retrace portion of the sweep to cut off the RF output. When the switch is in the ON position, the grid is connected to ground and the RF is on during the sweep retrace.

2-13 AMPLITUDE MODULATION

Refer to Figure 4-5 for this portion of the circuitry.

The grid of the BWO tube is at ground potential during sweep operation, so grid control can be achieved by varying only the cathode voltage. The BWO RF power can be changed from full output to cutoff by varying the cathode from zero to approximately +28 volts. This voltage is obtained from cathode follower V28. RF LEVEL potentiometer R165 is connected in a bridge circuit to vary DC grid voltage of V28 over the control range. Tube V9B connected as a diode prevents the BWO from drawing grid current by preventing the cathode from going negative.

For squarewave modulation of the RF, tube V27 is used as a multivibrator with a frequency range adjustable from approximately 800 to 1200 cps. Frequency adjustment is accomplished by potentiometer R156. Increased positive volts increases the multivibrator frequency. The squarewave output (amplitude approximately 50 volts) is taken from R161 and connected to the input of V28 through switch SW9 and the bridge network of R163 - R167. The positive 50 volt input to the bridge circuit is sufficient to drive the BWO to cutoff for any setting of RF level potentiometer R165. When switch SW9 is in the EXT MOD position, external modulation can be made by an input to jack S9.

2-14 MARKERS

The markers are short video pulses. They are electronically derived from the internal sawtooth voltage used to drive the non-linear amplifier in producing the RF output. The markers are thus related to the RF through the transfer characteristics of the non-linear amplifier. By obtaining the markers from the sawtooth voltage instead of the RF output, their circuitry is independent of the RF characteristics of the instrument, and can be used without change in the various models.

The generation of the two markers is accomplished by the circuitry shown in Figure 4-6. The operation is the same for both markers, so only Marker 1 which includes tubes V13, V12, V14 and V15A, will be discussed.

Three inputs are summed through R84, R85 and R86, to provide the input to amplifier V13B. Two of the inputs are seen to be the same as the inputs to the non-linear amplifier; namely, the voltage from the CW-START FREQUENCY control potentiometer and the linearly varying sweep voltage from the END FREQUENCY potentiometer. The third input is a positive voltage from MARKER 1 potentiometer R87. Thus, the resulting input is a sawtooth identical to the input of the non-linear amplifier except for DC level which depends upon the relative settings of CW-START and MARKER 1 potentiometers. Since the marker circuit uses the same sawtooth input except for DC level as the

non-linear amplifier, the marker is at all times synchronized with the sweep frequency. The voltage from R87 in adding to the sum of the voltages from CW-START and END FREQUENCY potentiometers determines the part of the sawtooth voltage which makes the summed input at V13B go through zero. When the summed input goes through zero, the circuit acts to produce a marker. For a marker to be generated, R87 has to be set at a positive voltage equal to or greater than the negative voltage set by the CW-START FREQUENCY potentiometer to allow the marker input sweep to go through zero volts.

V13 is a differential amplifier with one grid input - pin 2 - at ground reference and the other grid - pin 7 - connected to the summing network of R84 through R86. The push-pull output from the plates of V13 is connected to the input grids of cathode follower V12. The two halves of V12 act as a grid controlled full wave rectifier to produce in the cathode resistor R89 a rectified sawtooth wave with a lower limit of about 50 volts. The maximum levels of the two sides of the sawtooth are limited by the dynamic range of V13. This is of no consequence however, since it is used as an input to the cathode of V15A, and V15A grid is biased so that plate current flows only at the lowest portion or tip of the cathode waveform. This tip corresponds to the region of the reference sawtooth wave that reduces the input at V13B to zero. The output of V15A, in plate load resistor R97, is a negative triangular pulse of about 5-10 volts amplitude and with a base level of about +150 volts. It is coupled to the grid of cathode follower V14 right half, through resistors R92 and R93. The output of cathode follower V14 right half, is a short negative pulse of about 5 volts. V14 left half, is used as a diode limiter to prevent the base of the pulse from ever going positive due to circuit tolerances or changes.

MARKERS output connector S8 and tube V14 are made common to both marker circuits by using R97 as the plate load resistor for both V15A and V15B. MARKER AMPLITUDE potentiometer R90 and MARKER BALANCE potentiometer R88 are common to both marker circuits. MARKER BALANCE potentiometer R88 is used to equalize the DC levels of both circuits by changing the relative cathode currents of the input amplifiers. MARKER AMPLITUDE potentiometer R90 permits the simultaneous setting of the amplitude of the two markers from zero to 5 volts by simultaneously changing the grid bias on clippers V15A and V15B.

The overall gain of the circuit is such that the width of the marker is not more than .5 percent of the total sweep.

2-15 POWER SUPPLIES

Refer to Figure 4-7 for this portion of the circuitry.

+3000 Volts:

The secondary winding 5-6 of high voltage transformer T1 is connected to a voltage doubler circuit with rectifiers SR1 to SR6 charging C21 to 1500 volts during the positive half cycle and rectifiers SR7 to SR12 charging C22 to 1500 volts on the

negative half cycle. The supply output is sum of voltages across C21 and C22 which is total of 3000 volts. Resistors R69 through R72 serve as bleeders to drain off the high voltage charge on C21 and C22 when the circuit is de-activated.

-300 Volts:

The -300 volt supply is electronically regulated to maintain a highly constant output with minimum ripple and drift. Transformer T3, winding 2-9, furnishes the plate voltage for full wave rectifier V33 with an output of +450 volts across filter capacitor C30. R140 is a bleeder resistor to drain the charge off C30 when the circuit is de-activated. V34 serves as a series tube to drop the voltage to 300 by control of its grid. V38 is a differential amplifier with one grid connected to a precision resistor network sampling a proportional part of the output voltage, and the other grid connected to a fixed value relative to the plate as set by regulator tubes V36 and V37. Any change in the -300 volt output will cause a change in the grid inputs to produce a push-pull output from the differential amplifier. The amplified output of differential amplifier V38 is connected to the grids of V35 with the left half employed as an amplifier and the right half as a cathode follower. Connected in this manner the differential signal is effectively applied to the grid and cathode of the left half of V35 so it produces an amplified single ended output for controlling the grid of V34. Thus a very small variation in the -300 volt line would instantly appear highly amplified at the grid of V34 to produce the necessary correction to cancel the variations. The high amplification also reduces ripple to a minimum. The screen grid supply for V34 is obtained from rectifier circuit SR14, C35, R149 and 115 volt secondary of regulating transformer T4. Since the 115 volts from T4 is regulated, the +135 volts to the screen grid is very stable.

+300 Volts:

The +300 volt circuit operation is quite similar to the -300 volt supply except that the first differential amplifier V32 utilizes the precisely controlled -300 volt line as a stable reference instead of regulator tubes. This assures precisely equal positive and negative plate supplies which are necessary for marker circuit accuracy. The grids of V32 are at zero volts when the output is exactly +300 volts and any variation from +300 volts produces a difference error which is amplified and passed on to the grids of V31 in similar manner as in the -300 volt supply.

Solenoid Supply:

Refer to Figure 4-8 for this portion of the circuit.

The solenoid supply is current regulated by electronic control of a saturable reactor L201 with its gate winding in series with the rectifier SR201. The

voltage drop across one ohm resistor R209 is a measure of the solenoid current. A reference voltage of the same value as the drop across R209 is furnished by a resistor divider network R204, R205, R206 and regulator tube V201. V203 is a differential amplifier with the grid of left side connected to the negative terminal, pin 2, of the regulator tube V201, and the right half grid connected to R209 through R210. Since the drop across R209 opposes the drop across R205, the grid inputs to the differential amplifier are identical when the solenoid current is the proper value. R210 and C205 constitute a filter which prevents ripple across R209 from appearing at V203 right grid. Any solenoid current deviation from the correct value will appear as an amplified output to V202 grid. The change in plate current of V202 changes the reactance of the saturable reactor L201 and consequently the input voltage to rectifier SR201 until the error signal at the grids of V203 returns to nearly zero.

The DC power supply furnishing positive and negative voltage to operate V201, V202, and V203 is provided by the 125 volt secondary of T201, rectifiers SR202, SR203, and capacitors C202 and C203.

2-16 POWER AND SWITCHING

All primary power to the instrument is made through chassis connector S201, interconnecting cable connector P1, POWER switch S8 and the thermal switch located in the solenoid L203. All power is removed if the interconnecting cable is disconnected or the solenoid temperature exceeds 200° F. See schematic diagram.

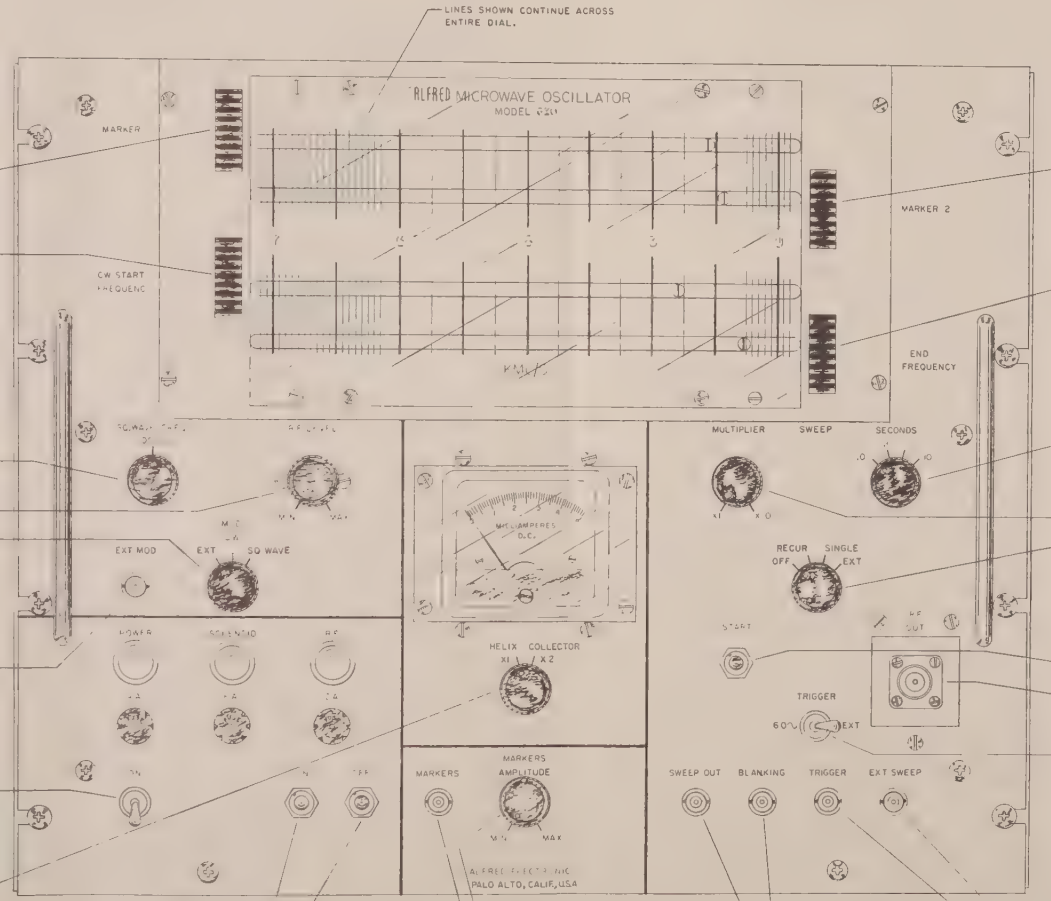
Separate fuses are provided for the solenoid, power and RF sections of the instrument.

The regulated power supplies, filament supplies, blower and solenoid are energized with the closing of POWER switch SW8. The high voltage power supply requires the additional closing of momentary RF ON switch SW7. The closing of SW7 applies 115 volts to holding relay RY1 through the normally closed contacts of relay RY2 and RF OFF switch SW6. The closing of relay RY1 contacts energizes the primary of high voltage transformer T1 and the plate of V19B in the BWO anode supply. The 6.3 volt winding of relay RY2 is connected through a normally open contact in overcurrent relay RY3 to filament supply U-U of transformer T2. If an overcurrent occurs, relay RY3 picks up and energizes relay RY2. The normally closed contacts of RY2 open to drop out RY1.

If the overcurrent relay RY3 or RF OFF switch SW6 drops out relay RY1, RF power, BWO tube anode, helix and collector voltages are removed until RF ON switch SW7 is again depressed.

Panel lights I1, I2, I3 are lit when their respective circuits are energized. The regulating transformer T4 furnishes a regulated supply through transformer T5 for all tube heaters that require closely held voltages.

SYM.	DESCRIPTION	NO.	DATE	BY



SET MARKER 1 FREQUENCY.

SET SWEEP START OR UNSWEPT FREQUENCY.

SET A.M. SQUARE WAVE FREQUENCY.

SET LEVEL OF R.F. OUTPUT.

SET MODE OF R.F. AMPLITUDE MODULATION — SQ. WAVE FOR INTERNAL SQUARE WAVE, C.W. FOR CONTINUOUS WAVE. EXT FOR EXTERNAL MODULATION.

CONNECT EXTERNAL R.F. AMPLITUDE MODULATION VOLTAGE.

PLACE TO ON TO APPLY POWER TO INSTRUMENT.

SET TO X1 TO READ BWO HELIX CURRENT. SET TO X2 TO READ BWO COLLECTOR CURRENT.

PRESS TO ENERGIZE HIGH VOLTAGE AND R.F. CIRCUITS. ALLOW A 3 MINUTE WARM UP.

PRESS TO DE-ENERGIZE R.F. CIRCUIT.

SET MARKERS AMPLITUDE 0-5V.

CONNECT TO EXTERNAL MARKERS PRESENTATION.

-75V BETWEEN SWEEPS FOR CONTROL OF EXTERNAL DISPLAY.

INTERNAL SWEEP SAWTOOTH OR INVERTED AND ATTENUATED EXTERNAL SWEEP VOLTAGE.

CONNECT TO EXTERNAL SWEEP VOLTAGE.

CONNECT TO EXTERNAL SWEEP TRIGGER.

SET MARKER 2 FREQUENCY.

SET END FREQUENCY OF INTERNAL SWEEP.

SET SWEEP PERIOD - COARSE

SET SWEEP PERIOD - FINE

SET SWEEP MODE — OFF FOR UNSWEPT OUTPUT, RECUR FOR REPETITIVE SWEPT OPERATION BETWEEN FREQUENCIES DETERMINED BY CW START AND END FREQUENCY INDICATORS, SINGLE FOR INTERNAL TRIGGERED SWEEP, EXT FOR SWEEP DRIVE BY AN EXTERNAL VOLTAGE.

PRESS TO INITIATE SINGLE SWEEP.

CONNECT TO R.F. LOAD.

SET TRIGGER MODE - EXT FOR SWEEP TRIGGERING BY START SWITCH OR BY EXTERNAL VOLTAGE. 60~ FOR INTERNAL 60CPS TRIGGER.

FIGURE 3-1

OPERATING CONTROLS

PANEL OPERATING CONTROL LAYOUT MODEL 620 SERIES			
TOL: FRAC ±1/64 DEC. ±.005 ANGLE ±1/2° UNLESS INDICATED OTHERWISE.			
ALFRED ELECTRONICS			
DRAWN	DATE	APPR'D	DWG. NO.
R.F.H.	6/18/60		39003A

SECTION 3 - INSTALLATION AND OPERATION

3-1 TRANSIT DAMAGE

Immediately upon receipt, carefully unpack and inspect the instrument for damage received from transit. Should any damage be found, follow procedure on "Shipment Damage Claim" page at the end of this manual.

3-2 POWER INPUT

Primary power requirements are 105 to 125 volts, 60 cps, 850 voltamperes. If operation at other voltages or frequencies is contemplated, consult manufacturer.

The three-conductor power cable supplied with this instrument is terminated in a polarized three-prong male connector recommended by the National Electrical Manufacturers' Association. The third contact is an offset round pin added to a standard two blade AC connector, and grounds the instrument chassis when used with an appropriate receptacle. To use this connector with a standard two-contact receptacle, only an adapter should be used that terminates the third contact in a short lead, which, when connected to the outlet mounting box will ground the instrument chassis.

3-3 MOUNTING

This instrument is designed for either bench or rack operation in normal ambient temperatures. When setting up on the bench, be sure air intake and exhaust on the sides of the unit are in the clear and air flow is unrestricted. For bench use and semi-portable applications, the Model 620 series Oscillator is normally supplied with sheet metal sides containing carrying handles.

If the instrument is to be rack mounted, the screws on each handle side including those at the edge of the panel, should be taken out and the sides removed. Unit is now ready for inserting into rack. Supports should be provided in the rack to carry the weight of the instrument upon insertion or removal. Also, air flow in the rack, to and from the instrument, must be adequate to prevent overheating.

3-4 OPERATING CONTROLS

In the following discussions panel controls are indicated by capital letters and underlined. Chassis controls are indicated by capital letters not underlined.

Refer to Figure 3-1 for the location of the panel controls and connectors.

POWER This switch controls all primary power to the instrument. Adjacent panel lamp indicates when power is on.

RF ON This button when pressed connects primary power to the high voltage transformers in the instrument and energizes a holding relay. Electrode voltages thereby are applied to the Backward Wave Oscillator tube. Adjacent panel lamp indicates when high voltage is on.

RF OFF This button de-energizes the holding relay to remove high voltage.

MARKER 1 This control provides linear frequency adjustment of an electronically generated short triangular marker pulse. The point of the marker pulse occurs when the RF frequency is the value indicated by the frequency dial. Accuracy is ±1%. The marker pulse may be summed into an external presentation for calibration purposes.

MARKER 2 This control provides linear frequency adjustment of a second electronically generated marker, of identical characteristics as Marker 1. Both marker voltages are brought out on panel MARKERS connector.

CW-START FREQUENCY This is a 10 turn control which precisely sets DC voltage applied to the Backward Wave Oscillator tube helix and therefore the frequency of the output signal. During non-swept operation it manually controls the output frequency. During internal sweep it determines the lower or sweep starting frequency.

END FREQUENCY This 10 turn adjustment controls the maximum value of BWO helix voltage and consequently the maximum operating frequency during swept operation. When using internal sweep, the frequency scan starts at CW-START FREQUENCY value and proceeds linearly in time to the END FREQUENCY value.

MOD This switch selects the type of amplitude modulation desired. In the EXT position connection is made to the adjacent EXT MOD connector. In the CW position, modulation of the RF signal is removed. In the SQ WAVE position, an internal square wave generator alternately turns RF on and off.

SQ WAVE FREQ This control sets the frequencies of the internal square wave generator and covers the range of 800 to 1200 cps.

RF LEVEL This control sets cathode bias on the BWO tube, which determines its beam current and RF output level.

HELIX X1 - COLLECTOR X2 This switch selects the panel meter to monitor the BWO helix or collector current with appropriate shunts. In HELIX X1

position, meter indicates helix current on a 5 ma scale. In COLLECTOR X2 position collector current is indicated on a 10 ma range.*

MARKERS AMPLITUDE This control simultaneously varies the amplitude of both frequency marker pulses from 0 to 5 volts or greater.

OFF-RECUR-SINGLE-EXT This switch determines the voltage waveforms applied to the BWO tube helix and hence the type of frequency variation.

In OFF position a DC voltage determined by the CW-START FREQUENCY knob, is fed to the BWO tube helix to produce a single, manually set frequency.

In RECUR position an internal sawtooth voltage is selected to scan repetitively, the frequency of the RF signal, linearly from low to high over the range bounded by CW-START FREQUENCY and END FREQUENCY dial settings.

In SINGLE position a single ramp voltage is applied to the BWO tube. This produces a linear increase of RF output frequency from low to high over the range bounded by CW-START FREQUENCY and END FREQUENCY dial settings. Upon arrival at uppermost frequency, rapid retrace occurs. Output frequency remains at starting value until sweep is initiated again. Single sweep may be started manually by panel START button, electronically by an external signal, or repetitively by an internal power line frequency (60 cps) trigger.

In EXT position, signals applied to EXT SWEEP connector will be amplified and fed to the BWO tube helix. RF output frequency will vary in proportion to the external voltage.

SECONDS This switch determines the basic period of the internal sweep generator including flyback time.

MULTIPLIER This control provides X1 to X10 multiplication of the sweep plus flyback interval. Flyback time is constant and in the X1 position is approximately 18% of total period. As MULTIPLIER control is rotated it becomes proportionally less. In X10 position it is about 1.8% of the total period.

START Pressing this button initiates single frequency sweep, when the SWEEP switch is in SINGLE position.

TRIGGER This switch selects the trigger for electronically starting single sweep. In the EXT position, a positive going signal 20 volts peak or greater, applied to the TRIGGER connector will initiate a single sweep. In the 60 ~ position, an internal waveform at power line frequency repetitively triggers the single sweep.

*On some models COLLECTOR X3 and a 15 ma range is used.

3-5 PANEL CONNECTORS

EXT MOD With MOD switch in EXT position, negative going signals applied to this connector are fed to the BWO cathode and will increase RF output. The external voltage adds to an internal bias of 0 to +25 volts set by the RF LEVEL control. Maximum bias voltage will cut off RF output and a negative 25 volt external signal adds to this to increase RF from zero to full value. A clipping diode prevents further control should signal exceed bias.

RF envelope response to modulating signals is DC to over 1 mc. When pulsed, rise and fall time can be as fast as 0.5 microseconds.

Output frequency will change slightly as RF level is reduced. This shift is usually less than 0.5%.

MARKERS Two triangular shaped pulses are available from this connector. The peak of one pulse occurs when RF output frequency is the value set by the MARKER 1 dial and the other by the MARKER 2 dial. The markers may be set for zero to -5 volts peak value by MARKERS AMPLITUDE control.

The markers may be summed out into an external presentation to indicate band limits or other specific frequencies in a swept frequency range. For example, when using a crystal detector, install a T adapter on its output and connect markers into one arm of the T. If an oscilloscope or recorder with balanced or differential input is being used with an unbalanced source, disconnect the grounded input terminal and connect markers output to it.

CAUTION: When using markers on an oscilloscope display with SWEEP OUT connected to the X-axis, phase shift in the oscilloscope X-axis will cause displacement of both RF frequencies and markers at fast sweep rates. Therefore to maintain a linear frequency display sweep SECONDS and MULTIPLIER controls should be set for periods long enough to prevent trace distortion.

SWEEP OUT Internal sweep sawtooth and ramp voltages as well as any applied external sweep voltages, are inverted, attenuated and brought out to the SWEEP OUT connector. When SWEEP switch is in RECUR or SINGLE position, SWEEP OUT voltage is a positive signal proportional to frequency, rising linearly with time from zero to +45 volts during the sweep interval. In the EXT position, the sweep out voltage is 0.225 times the external sweep signal and is opposite in phase. The output impedance is approximately 500 ohms.

BLANKING When SWEEP switch is on RECUR or SINGLE position, voltage at this connector is zero during sweep interval. During retrace and non-swept periods it is approximately -75 volts. This signal may be used to blank an oscilloscope or lift the pen on a plotter during retrace and between single sweeps. The output impedance is approximately 5000 ohms.

TRIGGER When SWEEP switch is in SINGLE position and TRIGGER switch in EXT position, positive going signals 20 volts or greater, applied to TRIGGER connector will start the frequency sweep. Any waveform may be used including pulses as short as 1 microsecond. The input impedance is approximately 100 K shunted by 100 μμf.

The sweep, once started, will be unaffected by subsequent triggers. However, it may be restarted any time after flyback commences. Should a trigger occur in this interval, a short premature sweep will occur. Flyback interval is 1.8 to 18% of total sweep period depending upon MULTIPLIER setting. Therefore, to prevent incorrect sweeps, the period of the triggering waveform should be longer than the flyback interval. In general, if sweep SECONDS and MULTIPLIER controls are set for sweep periods no greater than 4 times trigger period, no erroneous sweeps will occur.

EXT SWEEP When SWEEP switch is in EXT position, signals applied to EXT SWEEP connector will vary frequency of RF output from value set by CW-START FREQUENCY indicator and in proportion to the external voltage. Response to external sweep is DC to approximately 10 kc. Negative going signals increase frequency. 200 volts peak to peak will scan entire range. For example, with CW-START FREQUENCY at low end of band, an external voltage varying from zero to -200 volts will scan entire range. If CW-START FREQUENCY is set at band center, a variation from +100 to -100 volts will sweep entire band.

RF OUT The oscillator RF output is available from this connector.

3-6 SETTING-UP PROCEDURE

Refer to the above description for procedures in using the operating controls and panel connectors.

1. With POWER switch off, set panel controls:

   RF LEVEL to MIN
   MOD switch to CW
   CW-START FREQUENCY control to low end of band
   SWEEP switch to OFF
   METER switch to HELIX X1
   MARKERS AMPLITUDE to MIN.

2. Make appropriate connections to EXT MOD, MARKERS, SWEEP OUT, BLANKING, TRIGGER, and EXT SWEEP receptacles.

NOTE: For optimum performance of the instrument in measurement circuits, careful choice and use of detectors, RF cables, etc. must be made. Crystals can be used at any sweep speeds but most have frequency sensitive transfer characteristics. At medium sweep speeds bolometers give good performance in both frequency and sensitivity. Due to their long time constants, Barreters and Thermistors may only be used on the long sweep speeds. Avoid power losses by keeping RF cable lengths to a minimum and in good mechanical condition.

3. Turn POWER switch to ON, and note that blower should start. Allow 3 minutes warmup.

4. Set CW-START FREQUENCY control to desired frequency.

5. Press RF ON button. Note helix current should be negligible.

6. Slowly increase RF LEVEL control to MAX and note helix current should not exceed 2.5 ma. If helix current starts to exceed this value, set METER switch to COLLECTOR X2 position and note if collector current is in meter range. If too high, internal ANODE control requires resetting. If collector current is normal, BWO tube may require realignment in its solenoid to reduce helix current. Refer to the Maintenance Section of this manual for procedure in making these adjustments.

7. If operation is normal, RF output will be greater than 10 milliwatts and frequency within 1% of value indicated by CW-START FREQUENCY indicator.

8. Set MOD switch for amplitude modulation desired.

9. Set SWEEP switch for desired mode of sweep operation. If internal sweeps are to be used, set END FREQUENCY control to upper band limit and sweep controls, SECONDS and MULTIPLIER, for desired sweep interval.

   If single sweep mode is selected, the TRIGGER switch must always be placed in EXT position except when 60 ∿ triggering is desired. The EXT position is required for initiating the sweep by the START switch, or any external voltage applied to the TRIGGER receptacle. The 60 ∿ position of the TRIGGER switch only should be used when

the SWEEP switch is on .01 seconds and MULTIPLIER control at X.67 or less. 60 ∩ triggering of longer sweep periods will cause sweep initiation in the flyback interval and erratic sweeps.

10. Connect load to RF OUT. Correct coaxial load impedance is 50 ohms. Mismatch loads do not affect oscillator performance but will cause less power to be delivered.

11. Set MARKER 1 and MARKER 2 dial indicators to desired frequencies and MARKERS AMPLITUDE control for correct marker size.

12. Adjust RF LEVEL for desired power output. At the high end of the frequency range, output varies faster with RF LEVEL control than at the low end. Thus during swept operation, as RF LEVEL is reduced, output will go to zero at the high end of the band before the low end. If low level output is required without adjustment over the full range, set RF LEVEL near or at MAX and externally attenuate RF output. Automatic leveling control devices also may be used to hold RF output at a constant level over a desired frequency range by feeding an appropriate error control voltage to the EXT MOD connector.

3-7 TYPICAL SET-UPS

Figure 3-2 shows a typical equipment set-up for measuring the transfer characteristic of a RF device. Figure 3-3 shows the equipment and connections of a typical set-up in measuring the voltage standing wave ratio of a RF device.

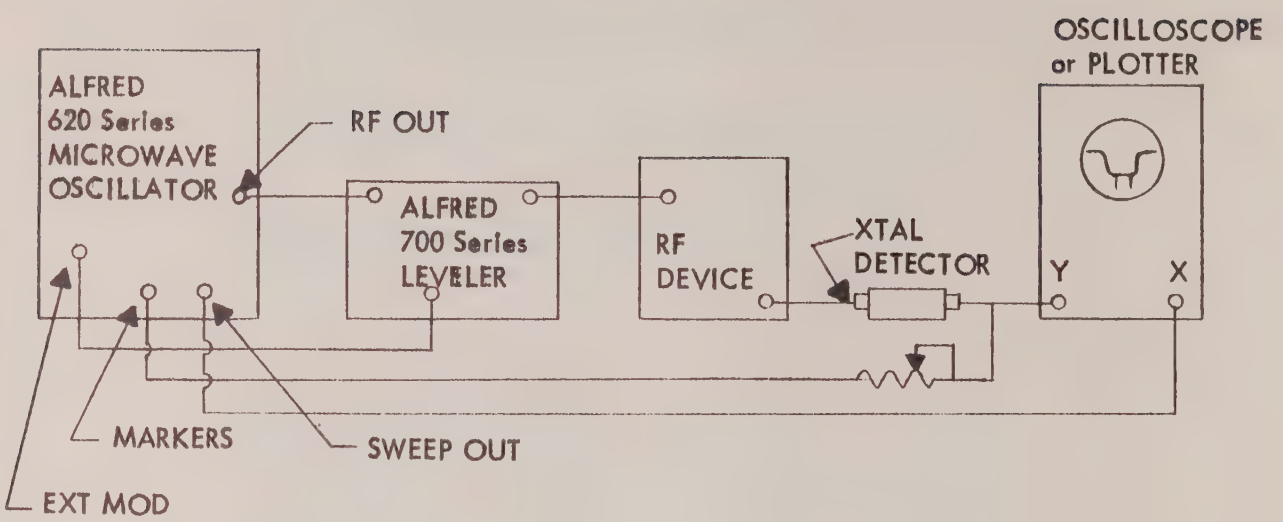


Figure 3-2
MEASURING TRANSFER CHARACTERISTICS OF RF DEVICE

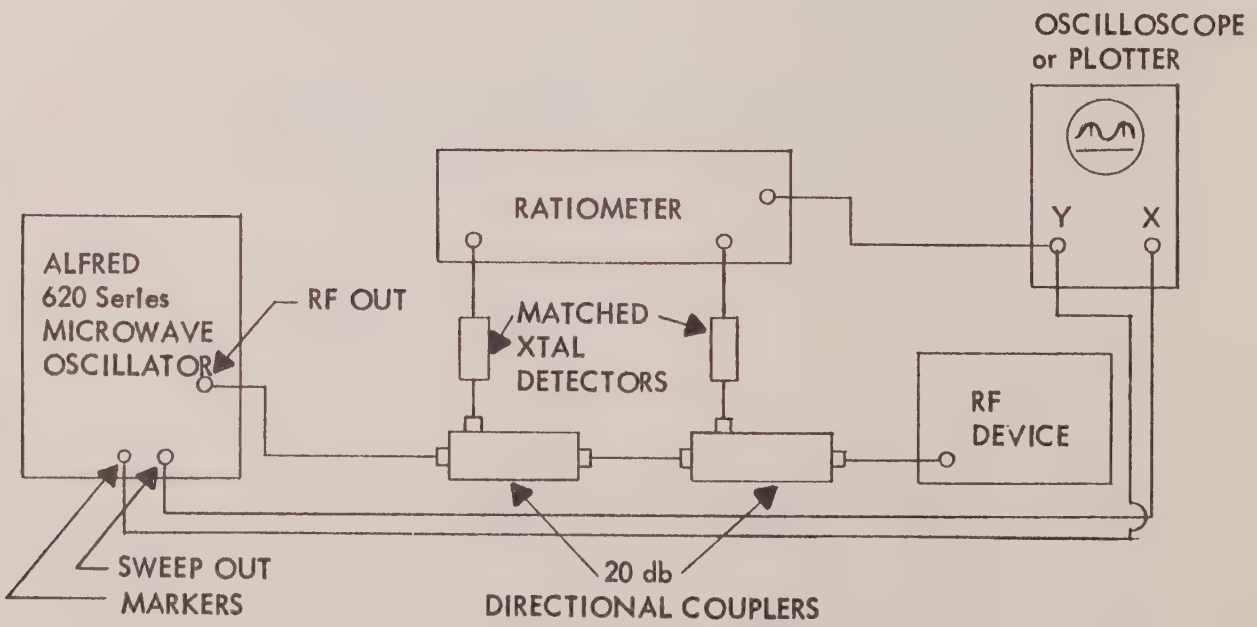


Figure 3-3
MEASURING VSWR OF RF DEVICE

SECTION 4 - MAINTENANCE

4-1 GENERAL

CAUTION: Dangerous high voltages exist in this instrument. Observe the utmost care when checking or making repairs. Voltages as high as 3000 volts are present at certain points in the instrument.

Reasonable care should be exercised in handling and transporting the equipment to prevent damage. Repairs should be undertaken only by qualified personnel and with sufficient and accurate test equipment. Carefully analyze difficulties before dismantling instrument. Do not make unnecessary repairs or adjustments as this may impair the accuracy of the equipment.

Study the schematic diagram and instrument layout to become familiar with the location of danger points. Use extreme care not to touch these points or short circuit them by a probe. Accidental shorts may cause severe component damage before the fuses blow and sometimes may cause high voltages to appear at otherwise low voltage points. Do not touch or try to remove any component in the high voltage section when power is on. Note that the cause of the overcurrent relay RY3 is at helix potential and may be as high as 2300 volts to chassis. Be sure that at all times the instrument chassis is grounded. The instrument chassis is internally connected to the grounding wire in the power cord and the NEMA 3 prong connector. Do not jeopardize your safety by removing the round pin in the connector or using a three prong to two prong adapter that will leave the chassis ungrounded.

4-2 PREVENTIVE MAINTENANCE

Preventive maintenance need only consist of removing dust cover and performing the following:

1. Oil blower motor once every six months with a few drops of SAE #20 oil. Blower failure for any reason will cause over-heating and possible damage to the BWO tube. Oil holes are on top of motor, one at each end.

2. At least once a year test all tubes on both upper electrode supply chassis and lower solenoid deck to detect marginal performance. Good tubes should be returned to their original sockets. Should a tube be replaced, associated controls should be recalibrated by procedures outlined later in this section. The following table lists the tubes which will affect calibration and the item affected. All other tubes may be replaced without adjustment.

   Tubes

V2	SINGLE SW ZERO
V4, V5, V6	SWEEP AMP
V9, V10	RECUR SW ZERO
V12, V13, V14, V15, V16, V17	MARKER BALANCE

V18, V19	START FREQ. CAL., END FREQ CAL., and ANODE
V27	Symmetry of square wave cathode modulation. Observe RF output when square wave modulated. Select tube for "on" time within 5% of "off" time.
V36, V37	-300 volt supply output. Select tubes for -300, ±3 volts.
V201, V203	Select tubes for correct voltage at SOLENOID I tip jacks. 3.7 ± .2 volts for Models 623 and below 4.0 ± .2 volts for Models 624 and up.

3. As the BWO tube ages, preset ANODE potentiometer on upper chassis may require readjustment to maintain adequate RF output across the frequency range when RF LEVEL setting is at MAX. However, do not advance ANODE beyond point where collector current is greater than the maximum range of panel meter. If adequate RF output cannot be obtained, BWO tube should be replaced. When ANODE is changed RF output frequency is also varied slightly. Calibration of CW-START FREQUENCY dial should be checked. Follow procedure in paragraph 4-8 for internal adjustments.

4. Periodically inspect the instrument for accumulated dirt and moisture. Forced air under medium pressure is recommended for cleaning and drying. Screws and nuts should be checked occasionally for tightness. Care should be taken to avoid changing any internal adjustments during cleaning and inspection as this will necessitate recalibration of the instrument.

4-3 TROUBLE SHOOTING

Should trouble occur, follow a logical procedure to locate the cause. Refer to Theory of Operation section and the schematic and block diagrams included in this manual. Typical voltages and waveforms are indicated on these diagrams. The following are some servicing suggestions that may lead to the correct remedial action with a minimum of disassembly and service time. In general a 20,000 ohm/volt meter is sufficient for measuring all voltages except at points of very high input impedances such as grids or plates having high plate resistors. In these measurements a digital, or VTVM, with at least a 10 megohm input impedance is recommended. For observing markers and waveforms, an oscilloscope with 10 meg input (X10 probe) is recommended.

1. Check fuses. Replace blown fuses with 250 volt, type 3AG.

2. Failure of the solenoid blower will cause overheating and may damage the BWO tube and solenoid. To minimize this danger, a normally closed thermal switch is installed in the solenoid to disconnect the primary power to the whole instrument if the solenoid temperature exceeds 200° F. Thus if fuses are good but instrument cannot be turned on, check for either defective blower or thermal switch. Blower rotor may be observed through air intake holes on left side, to see if it is up to speed. Thermal

switch may be checked with an ohmmeter on pins 5 and 6 of power socket S201 on solenoid deck. Remove bottom plate to get at this socket and be sure power cord is removed from electrical outlet.

3. If BWO helix current is high enough to trip out overcurrent relay, focusing magnetic field may be too low. Check solenoid current by connecting the positive lead of a high resistance DC voltmeter to the rear red test point TP201, and the negative lead to the black test point TP202. Meter should indicate 3.7 ± .2 volt for Models 623 and below, 4.0 ± .2 volt for Models 624 and up. If the voltage is incorrect, the solenoid supply is faulty. If correct, V20 may be defective or the BWO tube may need realignment. This procedure is described later in this section.

4. Remove dust cover and observe tubes to determine if heaters are operating and voltage regulators are lit.

5. If improper operation is indicated and power can be applied to the instrument without blowing fuses, check outputs of all panel receptacles to see if faulty operation exists in more than one general area. If two or more areas are indicated, in all probability a power supply is at fault.

   The +300 volt supply can be checked at the common end junction of MARKER 1 and MARKER 2 potentiometers (red lead).

   The -300 volt supply can be checked at the CW-START FREQUENCY potentiometer (lug near dial box - purple lead).

   The 3000 volt supply can be checked at the plate connector of tube V21. CAUTION: Have RF POWER "OFF" when making or breaking connections in this area.

6. If any of the above checks lead to a faulty power supply (see Figure 4-7).

   a. Check tubes, either by replacement method or by tube checker, in the faulty section.

   b. See if one of the circuits using the supply is excessively loading it. This may be done by removing tubes and/or checking resistances at various points.

   c. The approximate overall loading is as follows:

      +300 volts, 13 K to ground
      -300 volts, 22 K to ground
      3000 volts, 1.7 M to ground.

7. Low or no RF output

   a. Check helix and collector currents.

   b. If the currents are normal, the BWO tube or its RF connections may be defective.

   c. If the currents are not normal, the BWO electrode control voltages are probably incorrect. See Figure 4-4 and 4-5. Check tubes. Check solenoid supply, Figure 4-8. Check BWO electrode voltages as outlined in section 4-4.

4-4 BWO ELECTRODE VOLTAGE MEASUREMENT

Either remove solenoid deck according to procedure in section 4-5 or remove left handle side by loosening 5 side screws and 4 at edge of front panel. Disconnect BWO power plugs P2, P3 and set operating controls as follows:

1. CW-START FREQUENCY dial set at low end of band.
2. MOD switch to CW.
3. SWEEP switch to OFF.

BWO tube voltages may be measured in the following manner.

Heater: Connect AC voltmeter to pins B and C of S2. Voltage should be 6.0 to 6.6 volts.

Cathode: Connect the leads of a high resistance DC voltmeter to chassis ground and the one pin connector S3. With RF LEVEL at MAX voltage should be from -0.5 to -1.5 volts. With RF LEVEL at MIN voltage should be about +27 volts.

Anode: Connect the positive lead of a high resistance DC voltmeter to pin A of S2 and the negative lead to chassis ground. Preset ANODE control will vary this voltage from about 25 to 300 volts. Reset after checking.

Helix: Connect the positive lead of a high resistance DC voltmeter to pin D of S2 and the negative lead to chassis ground. CW-START FREQUENCY control will vary helix voltage over rated values for the BWO tube. These should be within the rated range of 225 to 2300 volts. Check voltage readings against values on BWO data sheet.

Collector (above helix): Connect the positive lead of a high resistance DC voltmeter to pin E of S2 and the negative lead to pin D. Voltage should be 103 to 112 volts for any setting of CW-START FREQUENCY control.

Grid: Connect the negative probe of a high resistance DC voltmeter to pin F and the positive probe to chassis ground. When the SWEEP switch SW4 is in the OFF or EXT position, the grid voltage will be zero, when the SWEEP switch is in the SINGLE position, the voltage will be approximately -27 volts between sweeps. On RECUR position, the voltage is a rectangular pulse of zero to -27 volts amplitude which can be observed on the voltmeter if the SWEEP SECONDS switch and MULTIPLIER are set for a long sweep period. Retrace switch in OFF position.

4-5 CHASSIS DISASSEMBLY PROCEDURE

To gain access to underchassis components, set instrument upside down and remove bottom plate. Solenoid supply under chassis components are now accessible. For access to underside of electrode supply chassis, remove solenoid deck in the following manner:

1. Remove 6 screws at side edges of chassis that hold solenoid supply deck to the upper chassis.

2. Remove panel screws holding RF connector.

3. Disconnect octal power plug near panel power switches.

4. Slide solenoid chassis rearward about 4".

5. Disconnect plugs on BWO power cable and yellow cathode lead.

6. Chassis is now free. Use handle and rear edge for lifting. CAUTION: SOLENOID DECK WEIGHS 67 LBS. USE SAFE, CAREFUL PROCEDURE WHEN HANDLING DECK WITH BWO TUBE INSTALLED.

4-6 BWO TUBE REPLACEMENT

To replace the Backward Wave Oscillator tube, remove both gray handle sides by taking out the 5 side screws and 4 near the panel edge. Remove top dust cover.

Remove the screws on the panel RF OUT connector. Loosen the BWO locking screws available through LOCK holes in the upper chassis. From left side disconnect BWO power connectors and loosen clamp holding folded power cable.

Loosen two screws holding air manifold cover plate and slide it forward to free it. Slide the tube out the right end of the solenoid pulling power cable through the solenoid.

Follow reverse procedure in installing new tube, insert BWO until edge of slot at the RF output end of the capsule is in line with the end of the solenoid. Observe due caution to prevent damaging tube. Be sure to fold excess power cable and place it in the clamp on air cover plate.

Align tube according to procedure below except the ANODE control may need to be reset to obtain proper collector current when RF LEVEL setting is at MAX. Rated helix and collector currents are noted on data sheet furnished with new tube.

Frequency dial will also have to be calibrated to new BWO tube. Follow INTERNAL ADJUSTMENTS procedure for setting START FREQ CAL and END FREQ CAL potentiometers. Also spot check CW-START FREQUENCY indication at other frequencies in the band. Start and end frequencies may require slight change to bring entire dial scale within ±1% accuracy.

4-7 BWO TUBE ALIGNMENT

Alignment of the BWO tube is accomplished in the following manner:

1. Set controls as follows;

   RF LEVEL at MIN
   MOD switch to CW
   SWEEP switch to OFF
   CW-START FREQ about midband

2. Remove the top screen and loosen the two tube locking screws accessible through holes marked LOCK in electrode supply deck.

3. Carefully turn instrument upside down and remove bottom plate. Alignment screws are at an angle through holes in solenoid deck and the edges of solenoid end plates.

4. Turn on POWER switch. After about 1 minute, press RF ON button.

5. Position BWO tube with the adjusting screws to obtain the lowest helix current, all the while increasing RF LEVEL towards MAX. ADJUST CAREFULLY. DO NOT DAMAGE TUBE CAPSULE BY CRUSHING IT AGAINST SOLENOID.

Should helix current accidentally exceed 2.5 ma, overcurrent relay will shut off power supply. Operation can be restored by depressing RF ON button.

Positioning of the BWO tube is most easily accomplished with two screwdrivers, one in each hand. Starting with the tube approximately in the center of the hole, slowly wobble the tube with the alignment screws, to minimize helix current. Adjust, alternately, both front screws then both rear screws, and perhaps one front and one rear. After a minimum setting is reached, one screw should be turned, usually causing helix current to increase, and then the null relocated by turning a different screw. Often the new null is lower than the original. Reverse direction of turning if the new null is higher. With a little practice, helix current can usually be reduced to a safe value.

Slight rotation of the BWO tube may also result in a lower minimum. For best focusing, the RF output end of the BWO capsule should be as far in the solenoid as possible. Minimum helix current up to about 2.5 ma is quite safe. However, the lower the current the less chance that gas will be driven from the helix due to heating. Gas would soon damage the cathode emission and render the BWO tube inoperative.

Connect an RF power meter to RF OUT connector. Set RF LEVEL at MAX, MOD switch to CW, and meter switch to COLLECTOR X2. Move CW-START FREQUENCY control across entire band. Check RF power output to assure it is 10 milliwatts or greater. If necessary, reset ANODE potentiometer to obtain adequate output but do not increase collector current more than 2 ma beyond recommended value on BWO tube data page. If power cannot be measured, set ANODE for collector current about 0.5 ma above recommended value.

If difficulty is encountered either in reducing helix current or obtaining adequate RF output at low end of the band, reversing solenoid connections sometimes will improve performance. The solenoid is connected with the orange lead nearest the edge, a polarity which ordinarily gives best operation. Therefore, reversal should be tried only as a last resort. Remove all power to the instrument and follow CHASSIS DISASSEMBLY PROCEDURE to remove solenoid chassis. Reverse heavy orange and black leads on SOLENOID terminals and replace chassis. Connect power and continue alignment.

When satisfactory performance has been achieved, tighten locking screws enough to prevent tube from being axially displaced in the solenoid, but not so tight as to dent the tube capsule.

4-8 INTERNAL ADJUSTMENTS

By proper design and use of precision components, internal adjustments have been kept to a minimum. Normally, the factory settings need be changed only when a tube or other component has been replaced. See Figure 4-1 for location of adjustments.

RETRACE RF This toggle switch should be normally set in OFF position. A negative blanking voltage is applied to the BWO grid to cut off the electron beam during the sweep flyback interval. Thus RF output is turned off during retrace to provide a convenient zero reference level. However, when using a feedback type automatic leveling device that is not blanked during flyback, RETRACE RF switch should be set to ON position to prevent large error build up during flyback and loss of RF control at start of sweep.

MARKER BALANCE This potentiometer is set to equalize amplitude of the two marker pulses by balancing the cathode currents of V13 and V17. Connect the Y axis of an oscilloscope to MARKERS receptacle and the X axis to the SWEEP OUT connector. Set SWEEP switch to RECUR. Move MARKER 1 and MARKER 2 dial pointers into range between CW-START FREQUENCY and END FREQUENCY indicators. Adjust MARKER BALANCE potentiometer for equal marker amplitudes. If amplitudes cannot be equaled or fall below 5 volts with MARKERS AMPLITUDE potentiometer at MAX, try substituting new tubes in V12, V15, or V16 sockets.

START FREQ CAL This potentiometer determines BWO tube helix voltage at low end of the band. Set panel SWEEP switch to OFF and CW-START FREQUENCY to lowest frequency. With a wavemeter connected to RF OUT, adjust START FREQ CAL potentiometer to give correct frequency at lower edge of band.

On instruments with Serial No. 110 or below, this adjustment will affect the upper band limit, also. Therefore, on these models the two adjustments will have to be alternately varied until the two band ends are properly calibrated to the front panel dial.

END FREQ CAL This potentiometer produces a fine adjustment of the maximum BWO tube helix voltage. With SWEEP switch at OFF and CW-START FREQUENCY control at its highest frequency, observe RF output on a wavemeter and set END FREQ CAL control for correct frequency. If voltage adjustment is beyond range of END FREQ CAL potentiometers, jumpers on the precision resistors may have to be changed.

Clockwise rotation of END FREQ CAL potentiometer decreases resistance to increase RF frequency. Thus, if frequency is too low add jumpers as necessary to short input resistors R40 through R44 until proper frequency can be obtained.

If frequency is too high, remove jumpers. Note, that in order to retain correct frequencies during sweep, correspondingly lettered resistor in input string R45 through R49 must also be shorted. Example: If A (R40) is shorted, then a (R45) must also be shorted.

On instruments with Serial No. 110 and below, turn off high voltage and remove shield box over END FREQ CAL potentiometer. Resistance of the potentiometer is 100 K and clockwise rotation increases resistance and RF frequency. Thus if frequency is too low, remove jumpers on resistors. If too high, short out additional precision resistors. BE SURE HIGH VOLTAGE IS OFF WHEN WORKING ON RESISTORS! Any change in END FREQ CAL control or the resistors also will affect the START FREQ CAL setting so it must be rechecked.

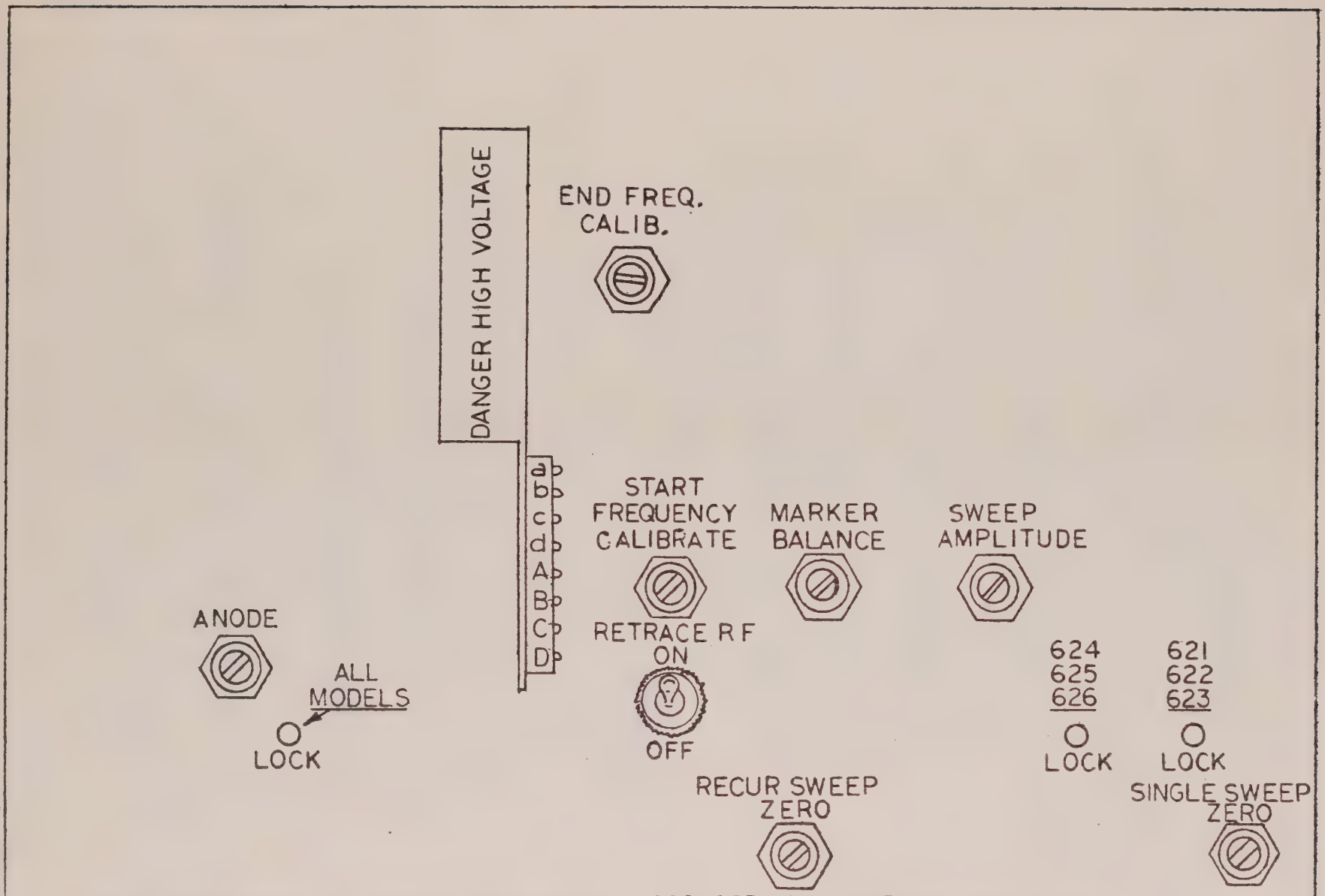
When first installing a new BWO tube, adjustment may be speeded by first using a DC voltmeter to indicate helix voltage. Connect positive lead to black lug with heavy black lead on top resistor board and the negative lead to chassis ground. Set START FREQ CAL and END FREQ CAL potentiometers for approximately the required voltages at each end of the band. These are indicated on the data sheet supplied with the BWO tube. Use a wavemeter for the final frequency calibration.

RECUR SWEEP ZERO This control adjusts the DC level at which recurrent sweep starts. Set SWEEP switch in RECUR position. Observe the negative going sweep voltage on a DC oscilloscope connected to the gray lead on the dial END FREQUENCY potentiometer. Adjust so that start of sweep occurs at exactly zero voltage. If a suitable oscilloscope is not available, zero voltage can be calibrated using a DC voltmeter at very slow sweep rates.

SINGLE SW ZERO Repeat above with the panel SWEEP switch at SINGLE, adjust SINGLE SW ZERO for zero volts.

SWEEP AMP Connect a DC calibrated oscilloscope or high accuracy meter to gray wire on the dial END FREQUENCY potentiometer. Adjust SWEEP AMPLITUDE control for exactly 200 ± 2 volts peak sawtooth sweep voltage. Sweep time must be set for a long interval if a meter is used so its needle will follow accurately.

ANODE This potentiometer sets the anode voltage to the BWO tube to obtain the correct operating currents for rated RF power output. When first installing a new BWO tube, first set ANODE control fully counterclockwise. Rotate clockwise to increase BWO tube currents to values indicated on tube data sheet. Slight readjustment from this value may be necessary to obtain rated RF output throughout frequency range.



ELECTRODE SUPPLY CHASSIS TOP VIEW 620 SERIES INTERNAL ADJUSTMENTS

FIGURE NO. 4-1 900257D ALFRED ELECTRONICS 9/4/59

4-9 DIAL ASSEMBLY REPAIR

The dial assembly requires no lubrication and ordinarily no maintenance. However, in the event of a potentiometer failure, follow the procedure outlined below to effect repairs. Refer to Assembly Diagram, Figure 4-9 for location and identification of parts.

1. Remove screws holding dust cover and slide it back about 6 inches. Remove the screw and washer holding cable clamp (A).

2. Unsolder leads to defective potentiometer and position its pointer at the left end of the dial.

3. Remove four 6-32 screws holding dial box panel (B) to instrument panel, lift the dial assembly up and lay it on top of the screen.

4. Remove plastic dial plate (C) and the fiber spacing washers. Remove four 6-32 flathead screws from dial box panel (B) freeing it from dial box (D). When reassembling make sure the arrows on the back of dial box panel (B) point toward the top.

Replacing MARKER 1 Potentiometer (E)

5. Set pointer (9) about 1" from left end of dial and do steps 1, 2, 3, and 4.

6. Loosen set screws (3) and slide spiral rod (4) off the potentiometer shaft. Remove nut and washer (1) using a 3/8" end wrench freeing potentiometer (E).

7. Insert new potentiometer, secure it with washer and nut (1) then turn its shaft fully counterclockwise.

8. Set pointer assembly (5) 1/32" away from the shoulder on spiral rod (4). Slide the rod onto all but 1/32" of the potentiometer shaft. Rotate the rod counterclockwise until the pointer faces directly up, then tighten one set screw (3) through opening in rear of dial box (D).

9. Remount dial box panel (B), loosen set screw (3) and turn knob (2) counterclockwise until edge of pointer (5) is 1/16" from end of slot. Tighten both set screws (3).

10. Reverse steps 1, 2, 3, and 4 to reassemble.

Replacing MARKER 2 Potentiometer (F)

11. Repeat steps 1, 2, 3, and 4.

12. Loosen two set screws (7) and slide spiral rod (8) to the right. Remove nut and washer (6) with a 3/8" end wrench freeing potentiometer (F).

13. Rotate shaft on new potentiometer fully counterclockwise, insert through the end plate (J), through washer and nut (6), and into the end of rod (8). Secure the potentiometer with washer and nut (6).

14. Set pointer assembly (9) 1/32" away from shoulder on spiral rod (8). Slide the rod onto all but 1/32" of the potentiometer shaft. Rotate the rod counterclockwise until the pointer faces directly up, then tighten one set screw (7) through opening in rear of dial box (D).

15. Remount dial box panel (B), loosen set screw (7) and turn knob (10) counterclockwise until the edge of pointer (9) is 1/16" away from end of slot. Tighten both set screws (7).

16. Reverse steps 1, 2, 3 and 4 to reassemble.

Replacing CW-START FREQUENCY Potentiometer (G)

17. Set pointers (9) and (25) about 1 inch from left end of dial slots. Repeat steps 1, 2, 3, and 4.

18. Loosen set screws (15) (between gear (13) and knob (14)) and slide rod (16) off the shaft of potentiometer (G).

19. Using an offset 3/8" box or end wrench, remove nut (12) freeing potentiometer (G) (or remove rod assembly (16) and remove nut with a 3/8" spin tite).

20. Insert new potentiometer with the spacing washer (11) into end plate (J). Secure the potentiometer with nut (12) then turn its shaft fully counterclockwise.

21. Set pointer assembly (17) 1/32" away from shoulder on spiral rod (16). Slide the rod onto the potentiometer shaft leaving 1/32" spacing between nut (12) and rod (16).

22. Loosen set screws on gear (13) and rotate rod (16) counterclockwise until pointer faces directly up. Tighten one set screw (15) through opening in rear of dial box (D).

23. Set pointer assembly (25) 1/32" away from shoulder on spiral rod (24). Rotate the rod clockwise until the potentiometer (H) starts to rotate and the pointer (25) faces directly up.

24. Remount dial box panel (B), loosen set screw (15) and turn knob (14) counterclockwise until edge of pointer (17) is 1/16" away from end of slot. Tighten both set screws (15).

25. Turn knob (26) clockwise until edge of pointer is 1/16" away from end of dial. Tighten both set screws on gear (13). (Tighten one screw first without moving any knobs. Dial box panel (B) might have to be removed to do this.)

26. Reverse steps 1, 2, 3, and 4 to reassemble.

Replacing END FREQUENCY Potentiometer (H)

27. Repeat steps 1, 3, and 4.

28. Loosen set screws (23) and on gear (22) freeing potentiometer (H). Remove potentiometer and unscrew threaded steel bushing (19) with padded gas pliers.

29. Unsolder contact rings (18) and replace on new potentiometer per Figure 19 (Detail #2) unless ordered specifically as potentiometer (H) from factory. Screw bushing (19) on tightly with padded gas pliers and rotate the shaft fully clockwise.

30. Insert the potentiometer assembly through oilite bearing (20), through gear (22) and into the end of rod (24), making sure contacts (21) mate with contact rings (18). Tighten both set screws on gear (22) allowing minimum play (approximately .005") on other side of oilite bearing (20). Rotate gear (22) clockwise until it stops.

31. Set pointer assembly (25) 1/32" away from shoulder on spiral rod (24). Space 1/32" between end of rod and bushing (20). Rotate the rod clockwise until the pointer (25) faces directly up, then tighten one set screw (23) through opening in rear

of dial box (D).

32. Remount dial box panel (B), loosen set screw (23) and turn knob (26) clockwise until edge of pointer (25) is 1/16" away from end of slot. Tighten both set screws (23).

33. Reverse steps 1, 3, and 4 to reassemble.

Sources of Binding and Excessive Drag

1. Pointer rubbing on plastic dial plate (C) (Tap pointer down to approximately 1/32" above dial box panel (B)).

2. Knobs not centered, rubbing on edge of slot.

3. Nylon keeper screw in pointer assembly too deep.

4. Potentiometer shaft bent.

5. Rod (4) or (8) rubbing against potentiometer (E) or (F) shaft bushing (set for 1/32" spacing).

6. Rod (16) rubbing against nut (12). (Set for 1/32" spacing.)

7. Rod (24) rubbing against steel bushing (19).

8. Not enough clearance on either side of oilite bearing (21). (Move gear (22) to the right just enough to free it.)

4-10 CALIBRATION OF MARKERS

To check the marker calibration follow the procedure outlined below.

1. Calibrate CW-START FREQUENCY at left end center and right end of dial using a calibrated wavemeter connected to RF OUT.

2. Sum marker pulses into wavemeter presentation. See discussion under MARKERS receptacle for methods of connection.

3. Dial presentation of markers should be within 1% of frequency calibration at any point. If deviation occurs, try new tubes in V13 and V17 sockets. If necessary check other electrical components by resistance measurements. Normally tube replacement will bring calibration within limits unless a mechanical repair or disassembly to the dial assembly has occurred.

If the markers are out of calibration due to mechanical failure or disassembly, proceed as follows after the repair has been made. Refer to Figure 4-9.

MARKER 1

1. Set oscillator to sweep entire frequency band. Align MARKER 1 pulse with wavemeter pulse.

2. Loosen set screws (3) and rotate knob (2) until dial pointer (5) aligns with corresponding frequency line on dial plate (C). Tighten set screws (3).

3. Check several frequencies across the band. Readjust as in step 2 above, for ±1% accuracy anywhere on dial.

MARKER 2

1. Align MARKER 2 pulse with wavemeter pulse .

2. Loosen set screws (7) and rotate knob (10) until pointer (9) aligns with corresponding frequency line on dial plate (C). Tighten set screws (7) .

3. Again check other frequencies and readjust if necessary for ±1% accuracy.

4-11 BLOWER REPLACEMENT

Turn instrument upside down and remove bottom plate. Unsolder two blower motor connecting wires. Follow CHASSIS DISASSEMBLY PROCEDURE to free solenoid chassis. Remove chassis and place on a bench, top side up. Loosen cable clamp and screws holding air manifold cover plate at left side of solenoid. Slide off cover plate. Using a nut wrench take out four screws holding black blower housing on rearward side of manifold. Take care not to disturb the BWO tube. Also take out screw holding small single bracket on side of blower. Lift out blower.

To replace blower motor take off ring on the side. Loosen wheel set screw with an allen wrench and pull the wheel off the end of the motor shaft. The two stop nuts holding motor are now exposed on inside of housing. Their removal will free motor. Reassemble using reverse procedure. Be sure motor is mounted with oil holes up.

4-12 COAXIAL RF CONNECTOR

The panel coaxial type RF OUT connector used on several models contains a special series capacitor and a small fine wire DC return. A teflon sleeve

between the cable center conductor and the connector pin serves as the capacitor dielectric and silicon oil is added to improve dielectric strength. The cable center conductor is at the BWO helix potential of 225 - 2300 volts DC. The series capacitor isolates the high potential from the panel connector center pin. The small diameter wire connects the center pin to ground through a low DC resistance, but high RF impedance.

Should arc-over occur in the connector, the helix overcurrent relay in the instrument will trip out. However, should the fine wire burn open, high voltage may appear at the center pin upon reapplication of power. Therefore take care to avoid shock or damage to external equipment connected to RF OUT when checking for failure. Use a voltmeter to determine if center pin is at high voltage.

If the connector failure is suspected but cannot be verified from the panel, take off the right gray handle side and disconnect RF cable from the BWO tube by unscrewing brass cap. Use an ohmmeter between connector center pin and coax center conductor to determine if capacitor is shorted. If it has failed, remove panel screws holding connector and take out complete cable assembly. Remove rear ring on connector and disassemble it. If no simple repair is possible the entire assembly should be replaced. Install new part carefully and reassemble instrument.

4-13 WARRANTY

All workmanship and materials except Backward Wave Oscillator tubes are guaranteed for one year. Details concerning warranty adjustments are presented on "Shipment Damage Claim" page at the end of this manual.

The Backward Wave Oscillator tube supplied in the unit is guaranteed for 500 hours of use or one year whichever expires first. Cost of an in-warranty replacement BWO tube will be prorated according to tube life obtained or time from delivery, whichever is greater. To obtain warranty service, requests should include a description of the failure, factors leading to it, and an accurate estimate of operating hours. Use the tube service report supplied at the end of this manual. Be sure to answer all questions fully.

4-14 DC VOLTAGE CHECKS

The following are nominal DC tube voltages measured with a digital voltmeter (10 megohm input). A 20,000 ohm/volt meter may be used but a slight allowance for its internal resistance must be made in the very high resistance circuits. A socket extender makes the voltages available at top of tube socket so disassembly of the instrument chassis is not required.

No.	Remarks	Pin Number 1	2	3	4	5	6	7	8	9
V1	TRIGGER-EXT									
	SWEEP-OFF	290	0	15	0	0	56	15	15	0
V2	SWEEP-OFF	300	2	7	0	0	260	0	7	0
V2	SWEEP-RECUR	Pin 6, 40 to 260								
V3	MULTIPLIER X1									
	SWEEP-OFF	15	15	39	0	0	300	260	260	0
V4	SWEEP-OFF					260				
V5	SWEEP-OFF					173				
V6	SWEEP-OFF		0		86					
V7	SWEEP-SINGLE	0	0	0	0	0	56	260	-10	0
V8	SWEEP-EXT	0	-86	-85	0	0	0	-85	-85	0
V9	SWEEP-EXT MOD-CW									
	RF LEVEL-MIN	-3	-283	-279	0	0	0	0	+26	0
	RF LEVEL-MAX	-3	-283	-279	0	0	0	0	-1.5	0
V10	SWEEP-OFF	+260	-105	0	0	0	47	0	0	0
V10	SWEEP-SINGLE	86	-86	0	0	0	275	0	0	0
V11	SWEEP-OFF	300	32	39	0	0	0	0	0	0
V11	SWEEP-RECUR		+32 to -63	+39 to -62			0 to -81			
V12	MARKER 1 CIRCUIT, MARKER POINTER AT MID-SCALE, CW-START AT LOW END. END FREQUENCY AT HIGH END									
	SWEEP-OFF	300	85	86	0	0	300	24	86	0
	SWEEP-RECUR	300 to 85	17				300	111 to 24		
V13	SAME POINTER SETTINGS AS FOR V12									
	SWEEP-OFF	85	0	6	0	0	24	6	6	0
	SWEEP-RECUR	17 to 85	0	0 to 6	0	0	24 to 110	0 to 6	0 to 6	0
V14	SAME POINTER SETTINGS AS FOR V12									
	SWEEP-OFF	.5	.5	0	0	0	300	-.9	.5	0
V15*	SAME POINTER SETTINGS AS FOR V12									
	SWEEP-OFF	149	54	87	0	0	*	*	*	0
V16*										
V17*										

*MARKER 2 circuit approximately the same as MARKER 1 circuit values.

No.	Remarks	Pin Number								
		1	2	3	4	5	6	7	8	9
V18	RF CONTROL CIRCUIT, CW-START at LOW END, SWEEP-OFF, RF-ON	300	81	91	0	0	80	37	0	1.3
	CW-START at HIGH END	300	86	98	0	0	85	37	0	1.3
V19	SAME SETTINGS AS FOR V18									
	CW-START LOW	300	**	**	0	0	75	37	0	1.3
	CW-START HIGH	300	**	**	0	0	68	37	0	1.3
V20	SAME SETTINGS AS FOR V18									
	CW-START - LOW	161 volts (plate)			156	74			89	
	CW-START - HIGH	843			163	77			102	
V21, V22, V24, V25, V26 **										
V27	Amplitude Modulator MOD switch on SQ WAVE SQ WAVE FREQ near mid-point ***	195	195	25	0	0	195		24	0
V28	Amplitude Modulation, MOD switch on CW									
	RF LEVEL MIN	26					300	300	300	14
	RF LEVEL MAX	-1.5					300	300	300	-23
V29	+300 volt supply							460		
V30	+300 volt supply	281	300	300		460		300		
V31	+300 volt supply	300	105	107	0	0	281	105	107	0
V32	+300 volt supply	105	0	2	0	0	105	0	2	0
V33	-300 volt supply							160		
V34	-300 volt supply	-16	0	0		160		0	135	
V35	-300 volt supply	0	-92	-93	0	0	-16	-93	-93	0
V36	-300 volt supply	0	-87							
V37	-300 volt supply					-87		-174		
V38	-300 volt supply	-92	-174	-173	0	0	-93	-174	-173	0
V201	Solenoid Supply	99	25							
V202	CAUTION - HAVE	99	80	215	0		215	215	215	80
V203	POWER OFF WHEN REMOVING OR REPLACING SOLENOID TUBES	99	24	26	0	0	80	25	26	0

**Values depend on Model. Use schematics and BWO helix versus frequency curve in arriving at correct values.

***Average DC values, see Figure 4-5 for wave shapes.

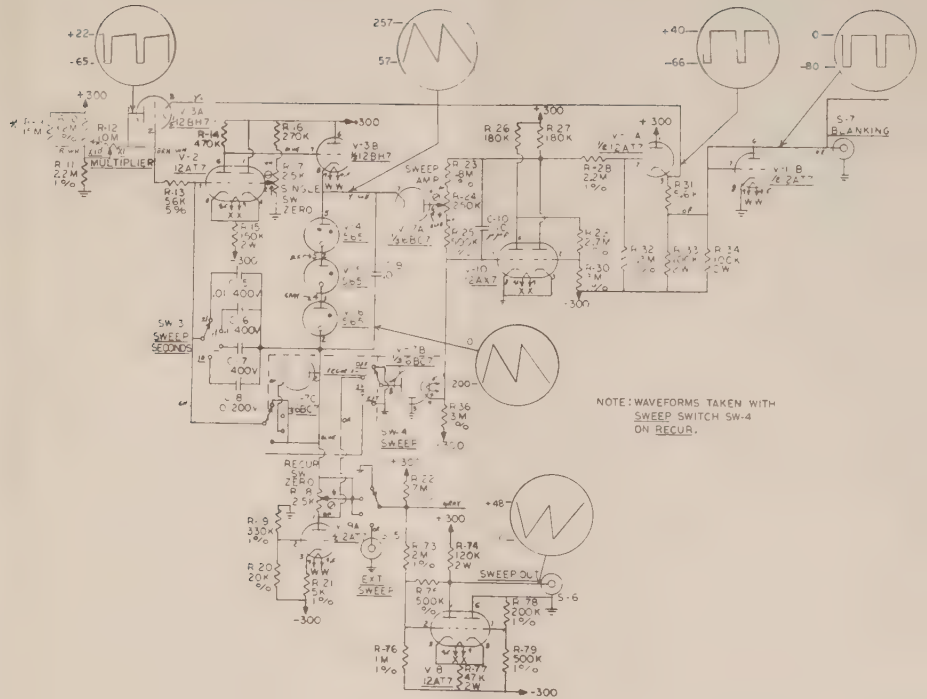


FIGURE 4-2
SWEEP GENERATOR

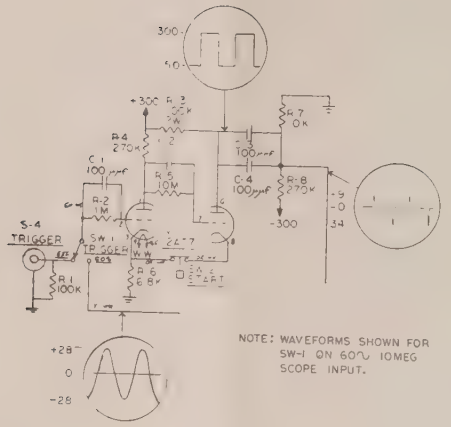


FIGURE 4-3
SCHMITT TRIGGER

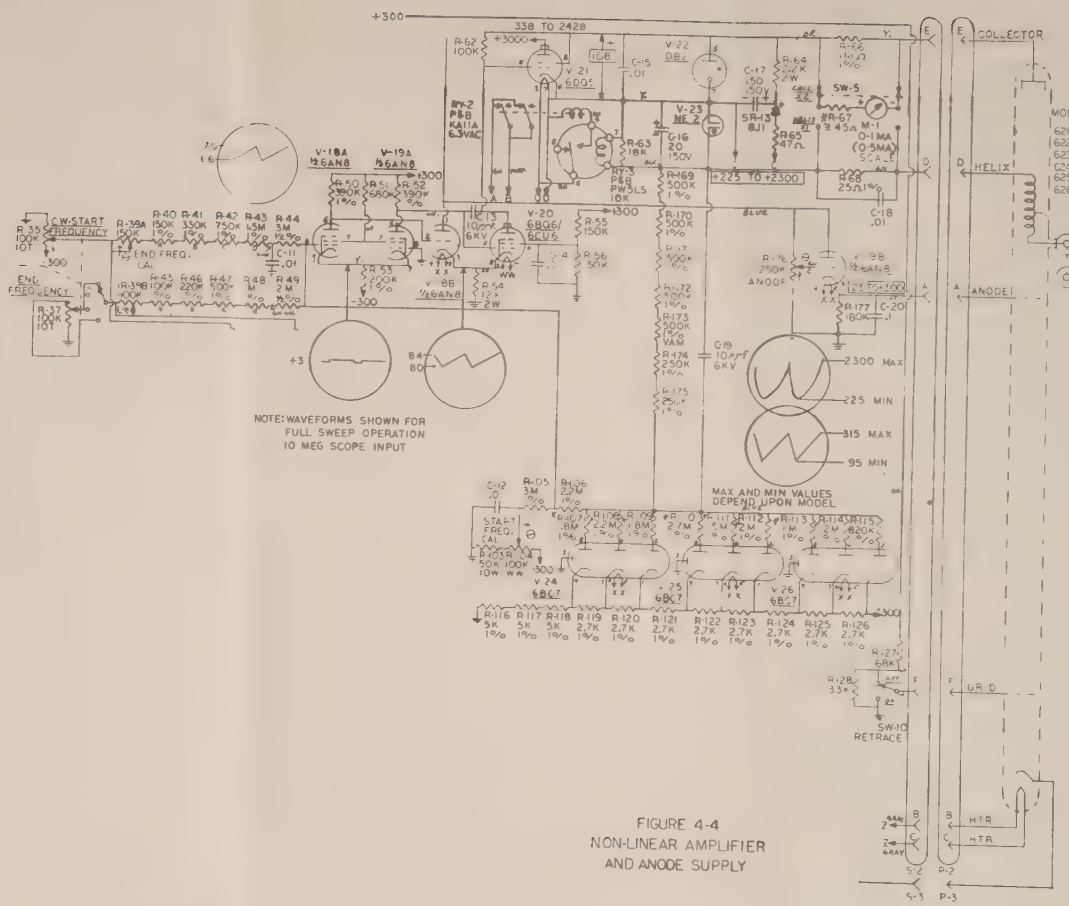


FIGURE 4-4
NON-LINEAR AMPLIFIER
AND ANODE SUPPLY

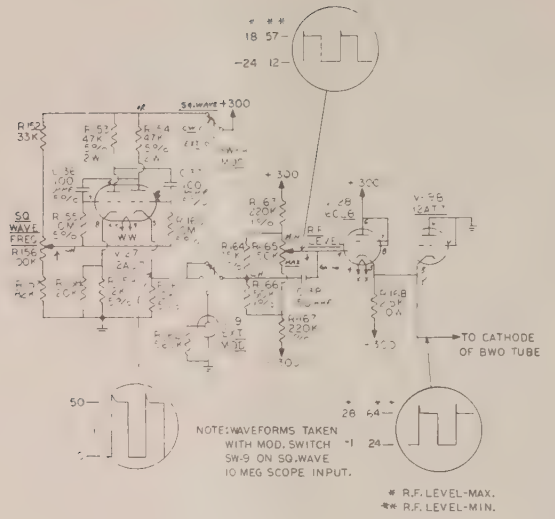
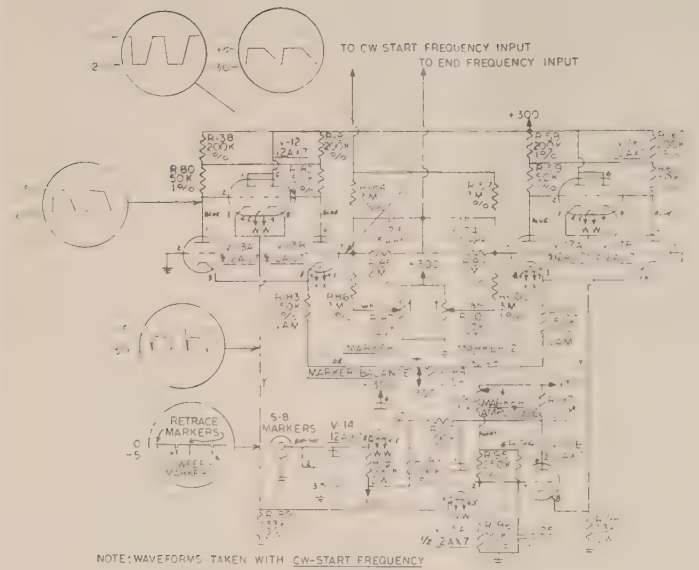


FIGURE 4-5
AMPLITUDE MODULATOR



NOTE: WAVEFORMS TAKEN WITH CW-START FREQUENCY SET AT LOWEST FREQUENCY AND END FREQUENCY AT MAXIMUM.
MARKER 1 POT R-87 SET AT APPROXIMATELY MID-SCALE, AND SWEEP SWITCH SW-4 ON RECUR.
10 MEG SCOPE INPUT.
MARKER 2 WAVEFORMS IDENTICAL.

FIGURE 4-6
MARKERS CIRCUIT

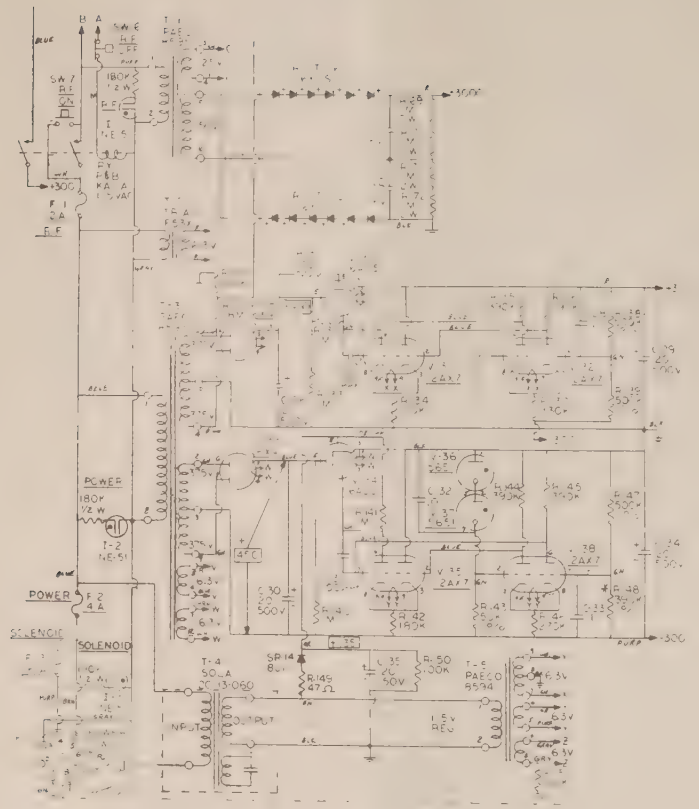


FIGURE 4-7
POWER SUPPLIES

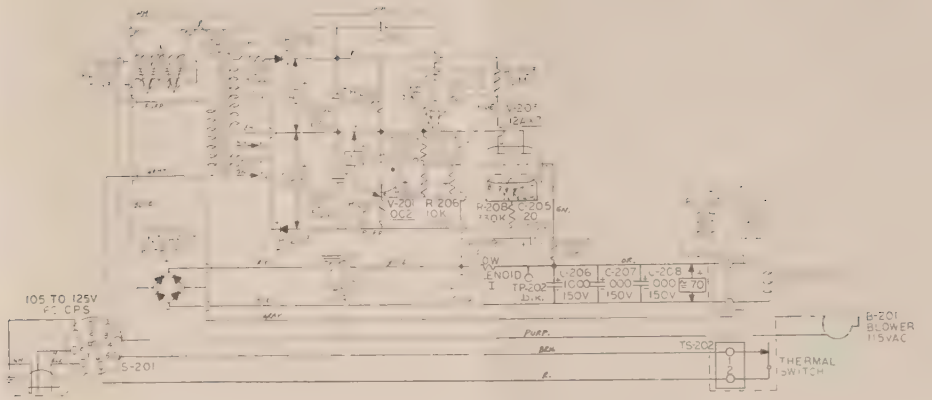
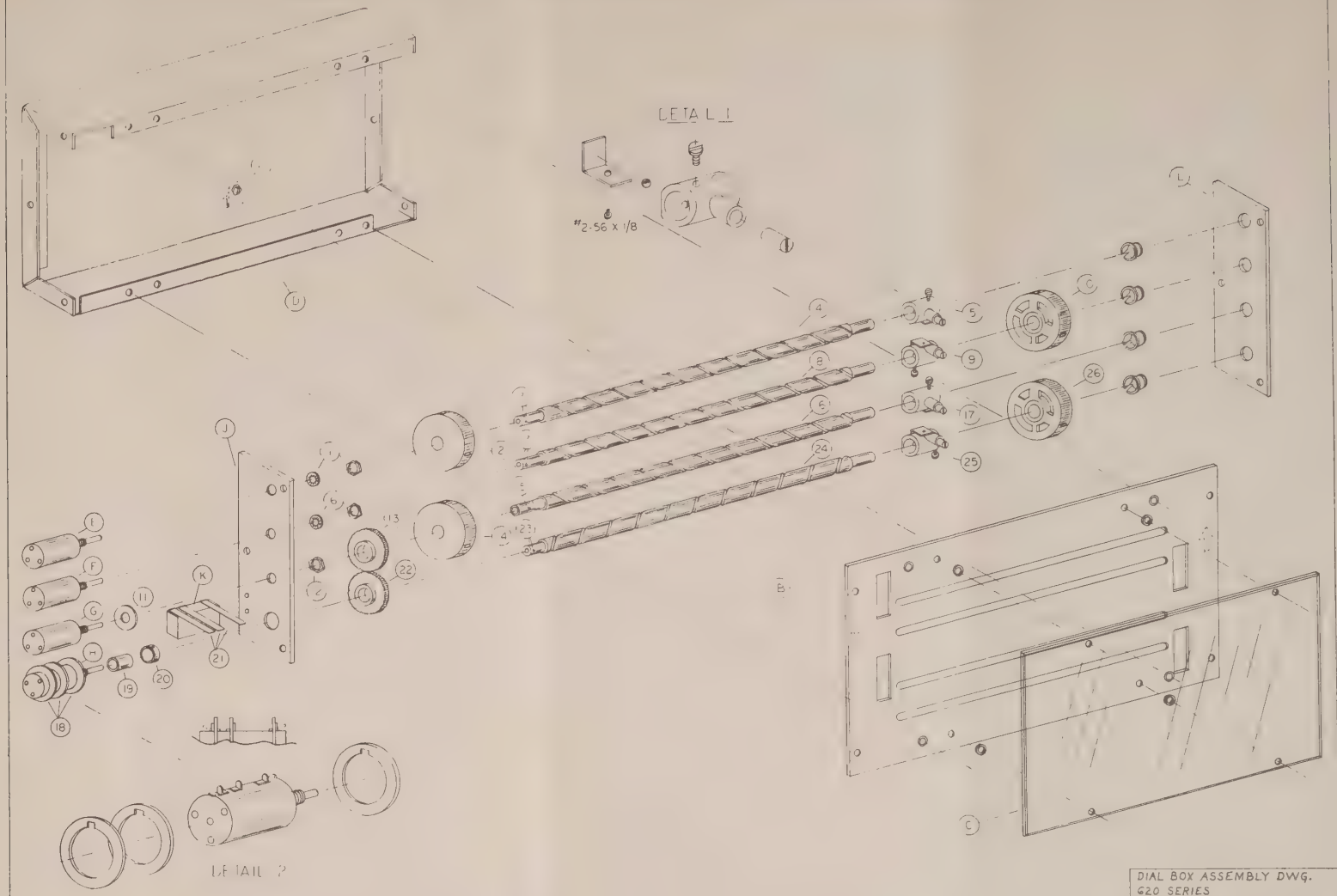


FIGURE 4-8
SOLENOID SUPPLY



DIAL BOX ASSEMBLY DWG.
G20 SERIES
990019B

SPEED ELECTRONICS

DRAWN	CHECKED	APPR'D	
R.F.H.	E.C.R.	L.F.D.	12/9/59

FIGURE 4-9

ELECTRODE SUPPLY CHASSIS
BOTTOM VIEW

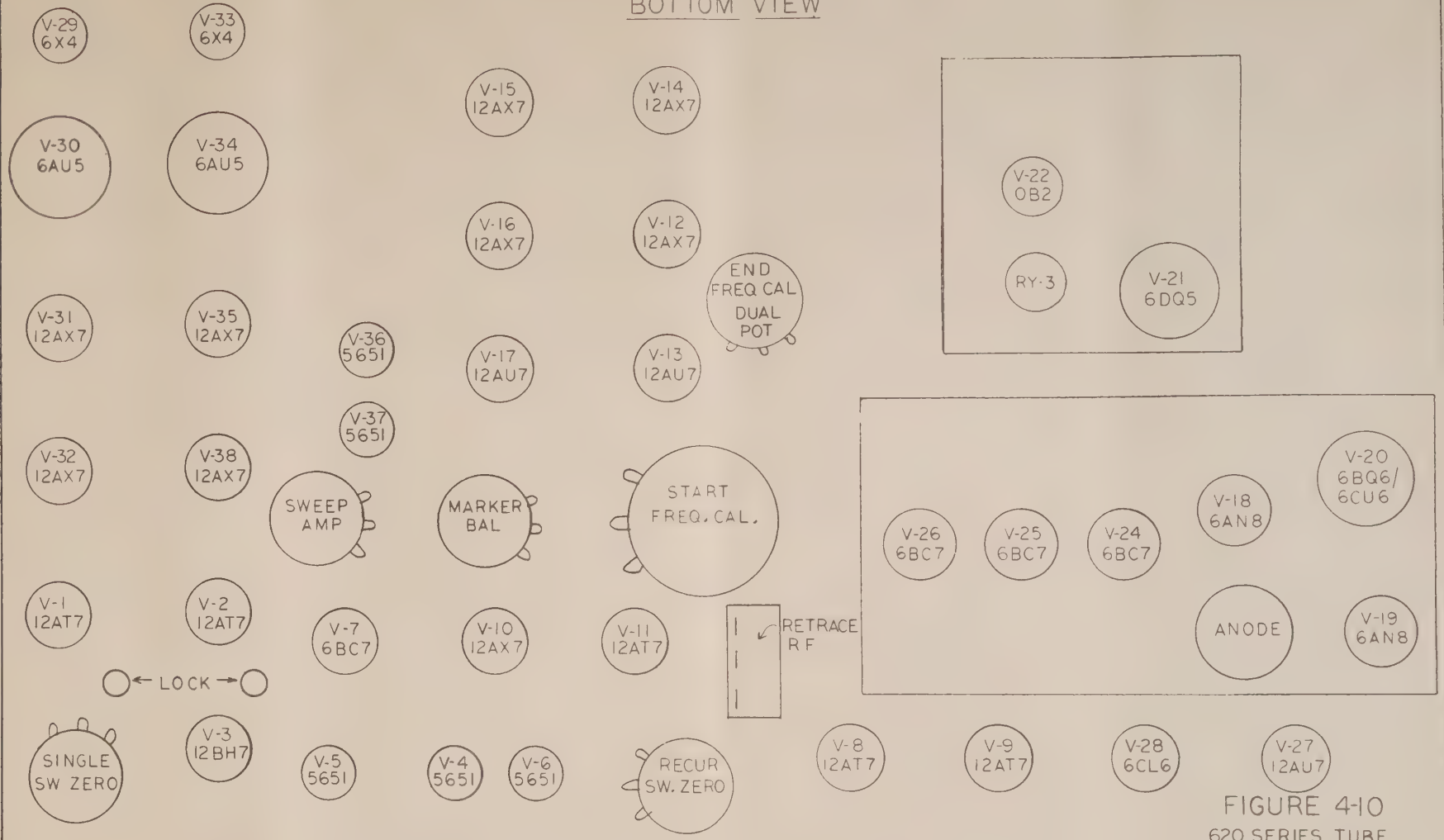
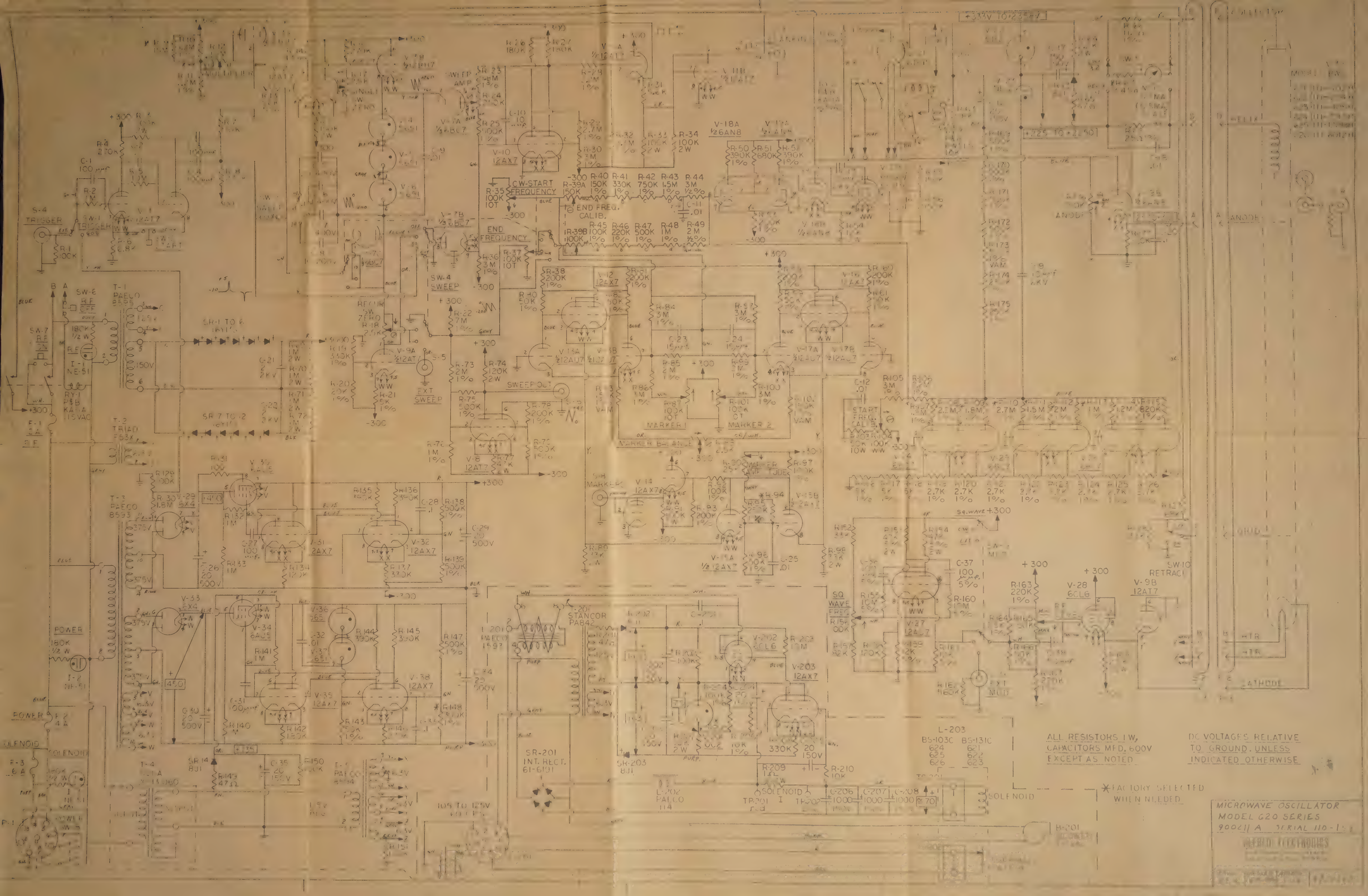


FIGURE 4-10
620 SERIES TUBE
LOCATION CHART


ALL RESISTORS 1 W, CAPACITORS MFD. 600V EXCEPT AS NOTED
DC VOLTAGES RELATIVE TO GROUND. UNLESS INDICATED OTHERWISE
* FACTORY SELECTED WHEN NEEDED
MICROWAVE OSCILLATOR
MODEL G20 SERIES
90021 A SERIAL 110-1
SR-201 INT. REG. 61-6191
L-203 BS-103C 624 625 626 BS-131C 621 622 623
L-201 PALCO 159
L-202 PALCO 114
T-1 PALCO 8595
T-2 TRIAD F68X
T-3 PALCO 8593
T-4 PALCO 8594
STANCOR PA842
SW-1 TRIGGER
SW-2 TRIGGER
SW-3 SWEEP
SW-4 SWEEP
SW-5 EXT SWEEP
SW-6 RF OFF 2W
SW-7 RF 2W
SW-8 MARKER
SW-9 MARKER
SW-10 RETRACE
SW-11 POWER
SW-12 POWER
SW-13 SQ WAVE FREQ
SW-14 START FREQ. CAL.
SW-15 END FREQ. CALIB.
CW-START FREQUENCY
END FREQUENCY
EXT SWEEP
SWEEP OUT
MARKER 1
MARKER 2
MARKER BLANKER
WAVEGUIDE AMP TUBE
EXT MOD
SQ WAVE +300
+225 TO +250
+333V TO +375V
SOLENOID
POWER
GRID
ANODE
CATHODE
HTR
V-1 6AT7
V-2 6AU6
V-3 6AU6
V-4 6AU6
V-5 6AU6
V-6 6BE6
V-7A 1/3 6BE7
V-7B 1/3 6BE7
V-8 12AT7
V-9A 1/2 12AT7
V-9B 12AT7
V-10 12AX7
V-11A 1/2 12AT7
V-11B 1/2 12AT7
V-12 12AX7
V-13A 1/2 12AU7
V-13B 1/2 12AU7
V-14 12AX7
V-15A 1/2 12AX7
V-15B 1/2 12AX7
V-16 12AX7
V-17A 1/2 12AU7
V-17B 1/2 12AU7
V-18A 1/2 6AN8
V-18B 1/2 6AN8
V-19 12AX7
V-20 12AX7
V-21 6AK5
V-22 6AK5
V-23 6AK5
V-24 6AK5
V-25 6AK5
V-26 6AK5
V-27 12AU7
V-28 6CL6
V-29 6X4
V-30 6X4
V-31 2AX7
V-32 12AX7
V-33 6X4
V-34 6AU6
V-35 12AX7
V-36 6BE6
V-37 6BE6
V-38 12AX7
V-201 6CL6
V-202 6CL6
V-203 12AX7
R-1 100K
R-2 1M
R-3 270K
R-4 270K
R-5 10W
R-6 6.8K
R-7 100K
R-8 100K
R-9 100K
R-10 1M
R-11 1M
R-12 100K
R-13 100K
R-14 100K
R-15 100K
R-16 100K
R-17 100K
R-18 2.5K
R-19 343K
R-20 20K
R-21 5K
R-22 7M
R-23 5M
R-24 200K
R-25 100K
R-26 180K
R-27 180K
R-28 2.7M
R-29 2M
R-30 3M
R-31 100
R-32 2.7M
R-33 100K
R-34 100K 2W
R-35 100K 10T
R-36 3M
R-37 100K 10T
R-38 200K
R-39A 150K
R-39B 100K
R-40 150K
R-41 330K
R-42 750K
R-43 1.5M
R-44 3M
R-45 100K
R-46 220K
R-47 500K
R-48 1M
R-49 2M
R-50 390K
R-51 680K
R-52 390K
R-53 200K
R-54 10K
R-55 200K
R-56 10K
R-57 200K
R-58 10K
R-59 3M
R-60 3M
R-61 10K
R-62 3M
R-63 2.5K
R-64 3M
R-65 2M
R-66 2M
R-67 2M
R-68 2M
R-69 2M
R-70 1M 2W
R-71 1M 2W
R-72 1M 2W
R-73 2M
R-74 120K 2W
R-75 500K
R-76 500K
R-77 4.7K 2W
R-78 200K
R-79 200K
R-80 50K
R-81 50K
R-82 50K
R-83 200K
R-84 3M
R-85 2M
R-86 3M
R-87 100K 10T
R-88 3M
R-89 2M
R-90 100K
R-91 100K
R-92 100K
R-93 200K
R-94 100K
R-95 100K
R-96 3.3K 2W
R-97 100K
R-98 50K
R-99 3.3K 2W
R-100 3M
R-101 100K 10T
R-102 100K
R-103 2.5K
R-104 3M
R-105 3M
R-106 4.7K
R-107 2.2M
R-108 1.8M
R-109 2.7M
R-110 1.5M
R-111 2M
R-112 1M
R-113 1.2M
R-114 820K
R-115 2.7K
R-116 2.7K
R-117 2.7K
R-118 2.7K
R-119 2.7K
R-120 2.7K
R-121 2.7K
R-122 2.7K
R-123 2.7K
R-124 2.7K
R-125 2.7K
R-126 2.7K
R-127 2.7K
R-128 100K
R-129 100K
R-130 1.8M
R-131 1M
R-132 1M
R-133 1M
R-134 120K
R-135 200K
R-136 50K
R-137 330K
R-138 500K
R-139 500K
R-140 1M
R-141 1M
R-142 130K
R-143 47Ω
R-144 330K
R-145 330K
R-146 330K
R-147 500K
R-148 500K
R-149 100K
R-150 100K
R-151 100K
R-152 33K
R-153 47K
R-154 47K
R-155 10K
R-156 82K
R-157 100K
R-158 82K
R-159 170K
R-160 2M
R-161 160K
R-162 160K
R-163 220K
R-164 1M
R-165 1M
R-166 270K
R-167 270K
R-168 10K
R-169 10K
R-170 10K
R-171 10K
R-172 10K
R-173 10K
R-174 2.5K
R-175 10K
R-176 10K
R-177 10K
R-178 10K
R-179 10K
R-180 10K
R-181 10K
R-182 10K
R-183 10K
R-184 10K
R-185 10K
R-186 10K
R-187 10K
R-188 10K
R-189 10K
R-190 10K
R-191 10K
R-192 10K
R-193 10K
R-194 10K
R-195 10K
R-196 10K
R-197 10K
R-198 10K
R-199 10K
R-200 10K
R-201 100K
R-202 100K
R-203 1M
R-204 100K
R-205 100K
R-206 330K
R-207 20 150V
R-208 10K
R-209 1Ω
R-210 10K
C-1 100 μμF
C-2 .01
C-3 .01
C-4 .01
C-5 .01
C-6 .01
C-7 .01
C-8 .01
C-9 .01
C-10 .10
C-11 .01
C-12 .01
C-13 .01
C-14 .01
C-15 .01
C-16 .01
C-17 .01
C-18 .01
C-19 .01
C-20 .01
C-21 .2 2KV
C-22 .2 2KV
C-23 15 μμF
C-24 15 μμF
C-25 .01
C-26 20 500V
C-27 100 μμF
C-28 .1
C-29 20 500V
C-30 20 500V
C-31 100 μμF
C-32 .01
C-33 .01
C-34 20 500V
C-35 20 150V
C-36 .01
C-37 100 μμF 5%
C-38 .01
C-39 .01
C-40 .01
C-41 .01
C-42 .01
C-43 .01
C-44 .01
C-45 .01
C-46 .01
C-47 .01
C-48 .01
C-49 .01
C-50 .01
C-51 .01
C-52 .01
C-53 .01
C-54 .01
C-55 .01
C-56 .01
C-57 .01
C-58 .01
C-59 .01
C-60 .01
C-61 .01
C-62 .01
C-63 .01
C-64 .01
C-65 .01
C-66 .01
C-67 .01
C-68 .01
C-69 .01
C-70 .01
C-71 .01
C-72 .01
C-73 .01
C-74 .01
C-75 .01
C-76 .01
C-77 .01
C-78 .01
C-79 .01
C-80 .01
C-81 .01
C-82 .01
C-83 .01
C-84 .01
C-85 .01
C-86 .01
C-87 .01
C-88 .01
C-89 .01
C-90 .01
C-91 .01
C-92 .01
C-93 .01
C-94 .01
C-95 .01
C-96 .01
C-97 .01
C-98 .01
C-99 .01
C-100 .01
C-101 .01
C-102 .01
C-103 .01
C-104 .01
C-105 .01
C-106 .01
C-107 .01
C-108 .01
C-109 .01
C-110 .01
C-111 .01
C-112 .01
C-113 .01
C-114 .01
C-115 .01
C-116 .01
C-117 .01
C-118 .01
C-119 .01
C-120 .01
C-121 .01
C-122 .01
C-123 .01
C-124 .01
C-125 .01
C-126 .01
C-127 .01
C-128 .01
C-129 .01
C-130 .01
C-131 .01
C-132 .01
C-133 .01
C-134 .01
C-135 .01
C-136 .01
C-137 .01
C-138 .01
C-139 .01
C-140 .01
C-141 .01
C-142 .01
C-143 .01
C-144 .01
C-145 .01
C-146 .01
C-147 .01
C-148 .01
C-149 .01
C-150 .01
C-151 .01
C-152 .01
C-153 .01
C-154 .01
C-155 .01
C-156 .01
C-157 .01
C-158 .01
C-159 .01
C-160 .01
C-161 .01
C-162 .01
C-163 .01
C-164 .01
C-165 .01
C-166 .01
C-167 .01
C-168 .01
C-169 .01
C-170 .01
C-171 .01
C-172 .01
C-173 .01
C-174 .01
C-175 .01
C-176 .01
C-177 .01
C-178 .01
C-179 .01
C-180 .01
C-181 .01
C-182 .01
C-183 .01
C-184 .01
C-185 .01
C-186 .01
C-187 .01
C-188 .01
C-189 .01
C-190 .01
C-191 .01
C-192 .01
C-193 .01
C-194 .01
C-195 .01
C-196 .01
C-197 .01
C-198 .01
C-199 .01
C-200 .01
C-201 .01
C-202 .01
C-203 .01
C-204 .01
C-205 .01
C-206 1000
C-207 1000
C-208 1000
C-209 .01
C-210 .01
C-211 .01
C-212 .01
C-213 .01
C-214 .01
C-215 .01
C-216 .01
C-217 .01
C-218 .01
C-219 .01
C-220 .01
C-221 .01
C-222 .01
C-223 .01
C-224 .01
C-225 .01
C-226 .01
C-227 .01
C-228 .01
C-229 .01
C-230 .01
C-231 .01
C-232 .01
C-233 .01
C-234 .01
C-235 .01
C-236 .01
C-237 .01
C-238 .01
C-239 .01
C-240 .01
C-241 .01
C-242 .01
C-243 .01
C-244 .01
C-245 .01
C-246 .01
C-247 .01
C-248 .01
C-249 .01
C-250 .01
C-251 .01
C-252 .01
C-253 .01
C-254 .01
C-255 .01
C-256 .01
C-257 .01
C-258 .01
C-259 .01
C-260 .01
C-261 .01
C-262 .01
C-263 .01
C-264 .01
C-265 .01
C-266 .01
C-267 .01
C-268 .01
C-269 .01
C-270 .01
C-271 .01
C-272 .01
C-273 .01
C-274 .01
C-275 .01
C-276 .01
C-277 .01
C-278 .01
C-279 .01
C-280 .01
C-281 .01
C-282 .01
C-283 .01
C-284 .01
C-285 .01
C-286 .01
C-287 .01
C-288 .01
C-289 .01
C-290 .01
C-291 .01
C-292 .01
C-293 .01
C-294 .01
C-295 .01
C-296 .01
C-297 .01
C-298 .01
C-299 .01
C-300 .01
C-301 .01
C-302 .01
C-303 .01
C-304 .01
C-305 .01
C-306 .01
C-307 .01
C-308 .01
C-309 .01
C-310 .01
C-311 .01
C-312 .01
C-313 .01
C-314 .01
C-315 .01
C-316 .01
C-317 .01
C-318 .01
C-319 .01
C-320 .01
C-321 .01
C-322 .01
C-323 .01
C-324 .01
C-325 .01
C-326 .01
C-327 .01
C-328 .01
C-329 .01
C-330 .01
C-331 .01
C-332 .01
C-333 .01
C-334 .01
C-335 .01
C-336 .01
C-337 .01
C-338 .01
C-339 .01
C-340 .01
C-341 .01
C-342 .01
C-343 .01
C-344 .01
C-345 .01
C-346 .01
C-347 .01
C-348 .01
C-349 .01
C-350 .01
C-351 .01
C-352 .01
C-353 .01
C-354 .01
C-355 .01
C-356 .01
C-357 .01
C-358 .01
C-359 .01
C-360 .01
C-361 .01
C-362 .01
C-363 .01
C-364 .01
C-365 .01
C-366 .01
C-367 .01
C-368 .01
C-369 .01
C-370 .01
C-371 .01
C-372 .01
C-373 .01
C-374 .01
C-375 .01
C-376 .01
C-377 .01
C-378 .01
C-379 .01
C-380 .01
C-381 .01
C-382 .01
C-383 .01
C-384 .01
C-385 .01
C-386 .01
C-387 .01
C-388 .01
C-389 .01
C-390 .01
C-391 .01
C-392 .01
C-393 .01
C-394 .01
C-395 .01
C-396 .01
C-397 .01
C-398 .01
C-399 .01
C-400 .01
C-401 .01
C-402 .01
C-403 .01
C-404 .01
C-405 .01
C-406 .01
C-407 .01
C-408 .01
C-409 .01
C-410 .01
C-411 .01
C-412 .01
C-413 .01
C-414 .01
C-415 .01
C-416 .01
C-417 .01
C-418 .01
C-419 .01
C-420 .01
C-421 .01
C-422 .01
C-423 .01
C-424 .01
C-425 .01
C-426 .01
C-427 .01
C-428 .01
C-429 .01
C-430 .01
C-431 .01
C-432 .01
C-433 .01
C-434 .01
C-435 .01
C-436 .01
C-437 .01
C-438 .01
C-439 .01
C-440 .01
C-441 .01
C-442 .01
C-443 .01
C-444 .01
C-445 .01
C-446 .01
C-447 .01
C-448 .01
C-449 .01
C-450 .01
C-451 .01
C-452 .01
C-453 .01
C-454 .01
C-455 .01
C-456 .01
C-457 .01
C-458 .01
C-459 .01
C-460 .01
C-461 .01
C-462 .01
C-463 .01
C-464 .01
C-465 .01
C-466 .01
C-467 .01
C-468 .01
C-469 .01
C-470 .01
C-471 .01
C-472 .01
C-473 .01
C-474 .01
C-475 .01
C-476 .01
C-477 .01
C-478 .01
C-479 .01
C-480 .01
C-481 .01
C-482 .01
C-483 .01
C-484 .01
C-485 .01
C-486 .01
C-487 .01
C-488 .01
C-489 .01
C-490 .01
C-491 .01
C-492 .01
C-493 .01
C-494 .01
C-495 .01
C-496 .01
C-497 .01
C-498 .01
C-499 .01
C-500 .01
C-501 .01
C-502 .01
C-503 .01
C-504 .01
C-505 .01
C-506 .01
C-507 .01
C-508 .01
C-509 .01
C-510 .01
C-511 .01
C-512 .01
C-513 .01
C-514 .01
C-515 .01
C-516 .01
C-517 .01
C-518 .01
C-519 .01
C-520 .01
C-521 .01
C-522 .01
C-523 .01
C-524 .01
C-525 .01
C-526 .01
C-527 .01
C-528 .01
C-529 .01
C-530 .01
C-531 .01
C-532 .01
C-533 .01
C-534 .01
C-535 .01
C-536 .01
C-537 .01
C-538 .01
C-539 .01
C-540 .01
C-541 .01
C-542 .01
C-543 .01
C-544 .01
C-545 .01
C-546 .01
C-547 .01
C-548 .01
C-549 .01
C-550 .01
C-551 .01
C-552 .01
C-553 .01
C-554 .01
C-555 .01
C-556 .01
C-557 .01
C-558 .01
C-559 .01
C-560 .01
C-561 .01
C-562 .01
C-563 .01
C-564 .01
C-565 .01
C-566 .01
C-567 .01
C-568 .01
C-569 .01
C-570 .01
C-571 .01
C-572 .01
C-573 .01
C-574 .01
C-575 .01
C-576 .01
C-577 .01
C-578 .01
C-579 .01
C-580 .01
C-581 .01
C-582 .01
C-583 .01
C-584 .01
C-585 .01
C-586 .01
C-587 .01
C-588 .01
C-589 .01
C-590 .01
C-591 .01
C-592 .01
C-593 .01
C-594 .01
C-595 .01
C-596 .01
C-597 .01
C-598 .01
C-599 .01
C-600 .01
C-601 .01
C-602 .01
C-603 .01
C-604 .01
C-605 .01
C-606 .01
C-607 .01
C-608 .01
C-609 .01
C-610 .01
C-611 .01
C-612 .01
C-613 .01
C-614 .01
C-615 .01
C-616 .01
C-617 .01
C-618 .01
C-619 .01
C-620 .01
C-621 .01
C-622 .01
C-623 .01
C-624 .01
C-625 .01
C-626 .01
C-627 .01
C-628 .01
C-629 .01
C-630 .01
C-631 .01
C-632 .01
C-633 .01
C-634 .01
C-635 .01
C-636 .01
C-637 .01
C-638 .01
C-639 .01
C-640 .01
C-641 .01
C-642 .01
C-643 .01
C-644 .01
C-645 .01
C-646 .01
C-647 .01
C-648 .01
C-649 .01
C-650 .01
C-651 .01
C-652 .01
C-653 .01
C-654 .01
C-655 .01
C-656 .01
C-657 .01
C-658 .01
C-659 .01
C-660 .01
C-661 .01
C-662 .01
C-663 .01
C-664 .01
C-665 .01
C-666 .01
C-667 .01
C-668 .01
C-669 .01
C-670 .01
C-671 .01
C-672 .01
C-673 .01
C-674 .01
C-675 .01
C-676 .01
C-677 .01
C-678 .01
C-679 .01
C-680 .01
C-681 .01
C-682 .01
C-683 .01
C-684 .01
C-685 .01
C-686 .01
C-687 .01
C-688 .01
C-689 .01
C-690 .01
C-691 .01
C-692 .01
C-693 .01
C-694 .01
C-695 .01
C-696 .01
C-697 .01
C-698 .01
C-699 .01
C-700 .01
C-701 .01
C-702 .01
C-703 .01
C-704 .01
C-705 .01
C-706 .01
C-707 .01
C-708 .01
C-709 .01
C-710 .01
C-711 .01
C-712 .01
C-713 .01
C-714 .01
C-715 .01
C-716 .01
C-717 .01
C-718 .01
C-719 .01
C-720 .01
C-721 .01
C-722 .01
C-723 .01
C-724 .01
C-725 .01
C-726 .01
C-727 .01
C-728 .01
C-729 .01
C-730 .01
C-731 .01
C-732 .01
C-733 .01
C-734 .01
C-735 .01
C-736 .01
C-737 .01
C-738 .01
C-739 .01
C-740 .01
C-741 .01
C-742 .01
C-743 .01
C-744 .01
C-745 .01
C-746 .01
C-747 .01
C-748 .01
C-749 .01
C-750 .01
C-751 .01
C-752 .01
C-753 .01
C-754 .01
C-755 .01
C-756 .01
C-757 .01
C-758 .01
C-759 .01
C-760 .01
C-761 .01
C-762 .01
C-763 .01
C-764 .01
C-765 .01
C-766 .01
C-767 .01
C-768 .01
C-769 .01
C-770 .01
C-771 .01
C-772 .01
C-773 .01
C-774 .01
C-775 .01
C-776 .01
C-777 .01
C-778 .01
C-779 .01
C-780 .01
C-781 .01
C-782 .01
C-783 .01
C-784 .01
C-785 .01
C-786 .01
C-787 .01
C-788 .01
C-789 .01
C-790 .01
C-791 .01
C-792 .01
C-793 .01
C-794 .01
C-795 .01
C-796 .01
C-797 .01
C-798 .01
C-799 .01
C-800 .01
C-801 .01
C-802 .01
C-803 .01
C-804 .01
C-805 .01
C-806 .01
C-807 .01
C-808 .01
C-809 .01
C-810 .01
C-811 .01
C-812 .01
C-813 .01
C-814 .01
C-815 .01
C-816 .01
C-817 .01
C-818 .01
C-819 .01
C-820 .01
C-821 .01
C-822 .01
C-823 .01
C-824 .01
C-825 .01
C-826 .01
C-827 .01
C-828 .01
C-829 .01
C-830 .01
C-831 .01
C-832 .01
C-833 .01
C-834 .01
C-835 .01
C-836 .01
C-837 .01
C-838 .01
C-839 .01
C-840 .01
C-841 .01
C-842 .01
C-843 .01
C-844 .01
C-845 .01
C-846 .01
C-847 .01
C-848 .01
C-849 .01
C-850 .01
C-851 .01
C-852 .01
C-853 .01
C-854 .01
C-855 .01
C-856 .01
C-857 .01
C-858 .01
C-859 .01
C-860 .01
C-861 .01
C-862 .01
C-863 .01
C-864 .01
C-865 .01
C-866 .01
C-867 .01
C-868 .01
C-869 .01
C-870 .01
C-871 .01
C-872 .01
C-873 .01
C-874 .01
C-875 .01
C-876 .01
C-877 .01
C-878 .01
C-879 .01
C-880 .01
C-881 .01
C-882 .01
C-883 .01
C-884 .01
C-885 .01
C-886 .01
C-887 .01
C-888 .01
C-889 .01
C-890 .01
C-891 .01
C-892 .01
C-893 .01
C-894 .01
C-895 .01
C-896 .01
C-897 .01
C-898 .01
C-899 .01
C-900 .01
C-901 .01
C-902 .01
C-903 .01
C-904 .01
C-905 .01
C-906 .01
C-907 .01
C-908 .01
C-909 .01
C-910 .01
C-911 .01
C-912 .01
C-913 .01
C-914 .01
C-915 .01
C-916 .01
C-917 .01
C-918 .01
C-919 .01
C-920 .01
C-921 .01
C-922 .01
C-923 .01
C-924 .01
C-925 .01
C-926 .01
C-927 .01
C-928 .01
C-929 .01
C-930 .01
C-931 .01
C-932 .01
C-933 .01
C-934 .01
C-935 .01
C-936 .01
C-937 .01
C-938 .01
C-939 .01
C-940 .01
C-941 .01
C-942 .01
C-943 .01
C-944 .01
C-945 .01
C-946 .01
C-947 .01
C-948 .01
C-949 .01
C-950 .01
C-951 .01
C-952 .01
C-953 .01
C-954 .01
C-955 .01
C-956 .01
C-957 .01
C-958 .01
C-959 .01
C-960 .01
C-961 .01
C-962 .01
C-963 .01
C-964 .01
C-965 .01
C-966 .01
C-967 .01
C-968 .01
C-969 .01
C-970 .01
C-971 .01
C-972 .01
C-973 .01
C-974 .01
C-975 .01
C-976 .01
C-977 .01
C-978 .01
C-979 .01
C-980 .01
C-981 .01
C-982 .01
C-983 .01
C-984 .01
C-985 .01
C-986 .01
C-987 .01
C-988 .01
C-989 .01
C-990 .01
C-991 .01
C-992 .01
C-993 .01
C-994 .01
C-995 .01
C-996 .01
C-997 .01
C-998 .01
C-999 .01
C-1000 .01

MICROWAVE OSCILLATOR
MODEL 623
Serial No. 146

BWO HEATER (S2 Pins B and C) (1 - 2)

E 6.15 (6.0 - 6.6) @ 105 v input, .75 amp load (R_L = 8.5 Ω, 10 w)

E 6.10 (within .12 v of 105 v reading) v AC @ 125 v input

INTERNAL SUPPLIES @ 115 v

-300 v - 300 (297 - 303)

Ripple 2 (<3) mv pk to pk (1 - 4)

+300 v + 299 (within 1 v of -300)

Ripple 2 (<3) mv pk to pk (1 - 3)

SWEEP GENERATOR

RECUR SWEEP ZERO OK ✓ (1 - 5)

SINGLE SWEEP ZERO OK ✓ (1 - 5)

Sawtooth @ V7, Pin 2 200 (199- 201) v pk to pk (1 - 5)

DC voltage @ SWEEP-OUT JACK -.2 (<± 1) (EXT sweep) (1 - 6)

Sawtooth @ SWEEP-OUT JACK 49 (45 - 50) v pk to pk (1 - 6)

Noise @ SWEEP-OUT JACK 20 (<25) mv (EXT sweep, SQ. WAVE on) (1 - 6)

BLANKING 76 (>75) v (1 - 7)

EXT. TRIGGER OK ✓ (1 - 7)

60∿ TRIGGER OK ✓ (1 - 7)

RETRACE SWITCH OK ✓ (1 - 8)

SWEEP TIME (1 - 8)

.01 x 1 .0100 (.0095 - .0105) sec.

.01 x 10 .100 (.095 - .105) sec.

.1 x 1 .098 (.095 - .105) sec.

.1 x 10 .99 (.95 - 1.05) sec.

1 x 1 .99 (.95 - 1.05) sec.

1 x 10 10.1 (9.5 - 10.5) sec.

10 x 1 10.1 (9.5 - 10.5) sec.

10 x 10 103 (95 - 105) sec.

MODEL 623
Serial No. 146

MARKER GENERATOR (S8) (1 - 9)

MARKER BALANCE set OK ✓

MARKER #1 min. 0 v, OK ✓ Max. >5 v, OK ✓

Phase shift 100 - 10 CPS less than 1% difference OK ✓ Width <0.5% OK ✓

MARKER #2 min. 0 v, OK ✓ Max. >5 v, OK ✓

Phase shift 100 - 10 CPS less than 1% difference OK ✓ Width <0.5% OK ✓

CATHODE (Pos. S3, Neg. chassis) (1 - 10)

RF LEVEL control at MAX. 0 load E_o -1.4 v (<0) Ripple 2 (<5) mv

RF LEVEL control at MAX. 10 ma load E_o -.2 v (<0) Ripple 3 (<5) mv

RF LEVEL control at MIN. 0 load E_o 26 v (>25) Ripple 3 (<5) mv

Internal square wave 1.25 (>1.25) ms min. to .73 (<.83) ms max.

1000 CPS centered on dial OK ✓

SQ. WAVE @ 1000 CPS on time / off time .95 (.95 - 1.05) rise time 0.4 (<1) μ sec.

fall time 0.8 (<1) μ sec.

EXT MOD (50 v square wave) OK ✓

ANODE SUPPLY (Pos. S2, Pin A, Neg. chassis) (1 - 11)

$E_{min.}$ 25 (<30) v @ .1 ma load Ripple 2 (<5) mv pk to pk (3 - 1)

$E_{max.}$ 300 (>275) v @ 0 load Ripple 2 (<5) mv pk to pk (3 - 2)

Noise at 150 v output 40 (<50) mv pk to pk (sweep on .01 sec.)

COLLECTOR (Pos. S2, Pin E, Neg. S2, Pin D)

E_o 109 (103 - 113) v @ 10 ma Ripple 60 (<100) mv (2 - 2, 3 - 3)

MODEL 623
Serial No. 146

HELIX (Pos. S2, Pin D, Neg. chassis) (All loads collector to ground) (2 - 3, 3 - 2, 4 - 1)

START FREQ. CAL. pot set at 225 v OK ✓

		SQ. WAVE OFF	SQ. WAVE ON
Ripple @ 225 v,	@0 load	50 mv (<50)	60 mv (<60)
Ripple @ 225 v,	@10 ma load (3 - 3)	40 mv (<50)	45 mv (<60)

END FREQ. CALIB. pot set at 2400 v (3 - 4, 4 - 2)

Ripple @ 2250 v	@0 load	60 mv (<150)	60 mv (<160)
Ripple @ 2250 v	@10 ma load (3 - 5)	60 mv (<150)	60 mv (<160)

Meter at 10 ma 10.0 ma (9.8 - 10.2) (2 - 4, 3 - 5, 4 - 1)

Meter at 5 ma 5.02 ma (4.9 - 5.1) (Load helix to ground) (R_L = 450 k, 25 w) (3 - 7)

Helix overcurrent relay trips @ 2.8 ma (2.5 - 3.00) (3 - 9)

Reg. @ 225 v, 0 load, 105 - 125 v line 20 mv (<50) (2 - 3, 3 - 2)

Reg. @ 225 v, 10 ma load, 105 - 125 v line 30 mv (<50) (3 - 3)

Reg. @ 225 v, 0 - 10 ma load, 115 v line 20 mv (<50)

Reg. @ 1075 v, 0 load, 105 - 125 v line 50 mv (<200)

Reg. @ 1075 v, 10 ma load, 105 - 125 v line 50 mv (<200)

Reg. @ 1075 v, 0 - 10 ma load, 115 v line 40 mv (<200)

INTERNAL SWEEP (2 - 3, 3 - 4, 4 - 2)

E_o sweeps to 2370 v (2225 - 2400)

EXTERNAL SWEEP

E_o sweeps to 2400 v (2225 - 2400) @ -200 v input

MODEL 623
Serial No. 176

DRIFT @ 1075 VOLTS

1st 1/2 hour 1.5 v 2nd 1/2 hour 0.1 v

2nd hour 0.2 v 3rd hour 0.5 v

SOLENOID

BS 131 CAE v set to 3.6 (3.5 - 3.9) v @ 115 v line (measure across R209)

BS 103 AE v set to _____ (3.9 - 4.1) v @ 115 v line (measure across R209)

Ripple 0.8 (<1.0) v pk to pk

Reg. 105 to 125 v line < .4 OK ✓

142

MODEL 623
Serial No. 146

RF TEST

Tube Model # 111-408H
Serial # 4246

Solenoid Model # BS-131AE
Serial # 37

Output greater than 10 mw across the band OK ✓

Dial	Limits	CW Start Freq.	Markers 1	Markers 2	f P max. to P min.	Helix I	Collector I
4	(3.96 - 4.04)	4.020	4.012	4.024	.010	0.4	4.0
4.5	(4.455 - 4.545)	4.470	4.455	4.470			
5	(4.95 - 5.05)	4.986	4.970	4.990			
5.5	(5.445 - 5.555)	5.522	5.510	5.535			
6	(5.94 - 6.06)	6.022	6.015	6.045	.020	0.45	4.1
6.5	(6.435 - 6.565)	6.520	6.510	6.545			
7	(6.93 - 7.07)	6.990	6.975	7.030			
7.5	(7.425 - 7.575)	7.480	7.460	7.520			
8	(7.92 - 8.08)	7.960	7.930	7.990	.020	0.7	3.9

END FREQ CALIB pot lock nut tightened OK ✓

SINGLE SWEEP ZERO set OK ✓ @ 4 kmc — Lock nut tightened OK ✓

RECUR SWEEP ZERO set OK ✓ @ 4 kmc — Lock nut tightened OK ✓

SWEEP AMPLITUDE OK ✓ @ 8 kmc — Lock nut tightened OK ✓

Blower oiled OK ✓

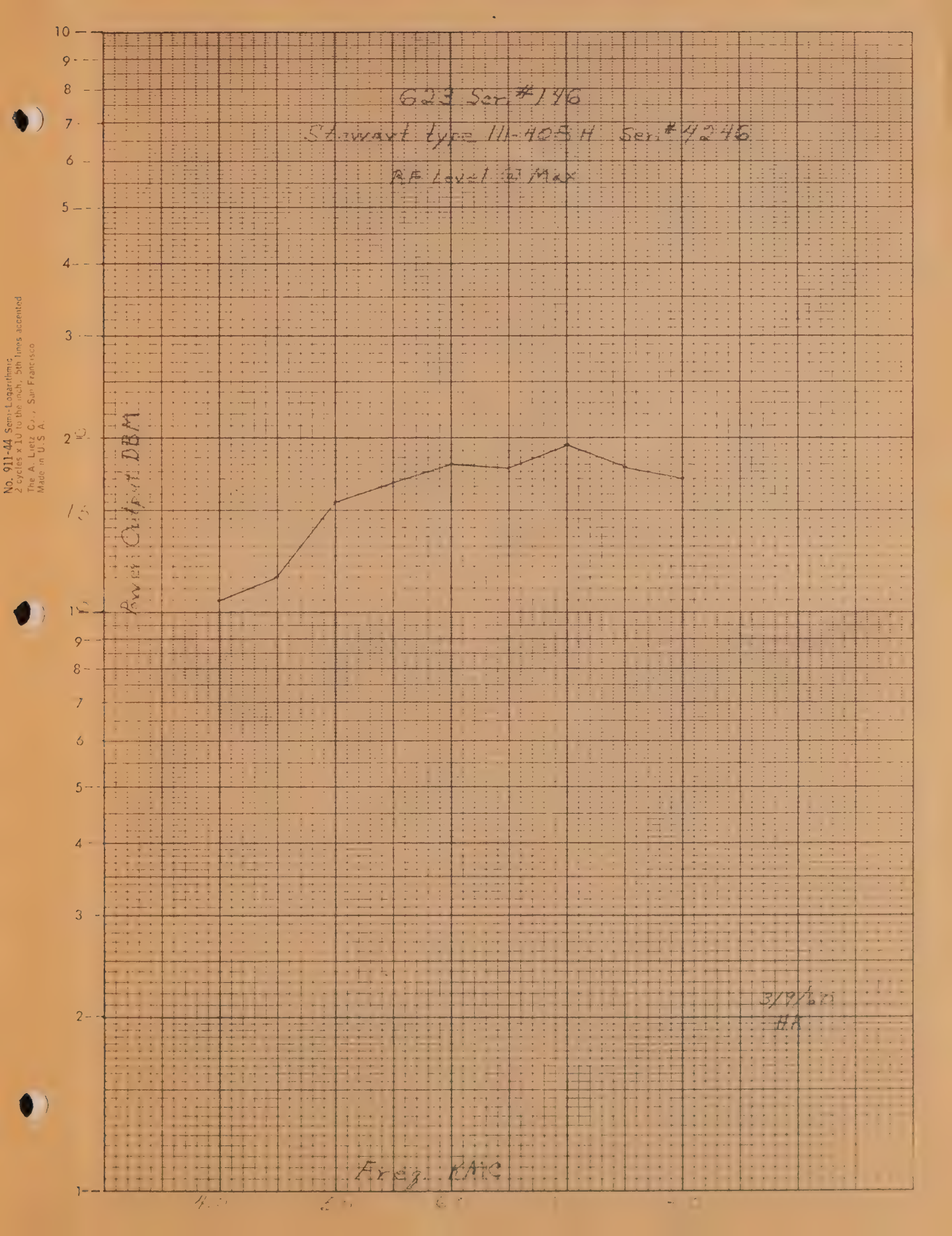
Tube locked down OK ✓

RF connector OK ✓

R107 1.8 Meg.
R108 2.2
R109 1.8
R110 2.7
R111 1.5
R112 2.0
R113 1.0
R114 1.2
R115 820K

Calibration Engineer HK

Date 3/9/60


623 Ser #146
Sawyer type III-405 H Ser #4246
RF Level @ Max
Power Output DBM
Freq KMC

SHIPMENT DAMAGE CLAIM

The instrument should be tested as soon as it is received. If it fails to operate properly or is damaged in any way, a claim must be filed with the carrier. Have carrier agent inspect damage to instrument and packing crate and forward to us a copy of his written report. You will then be advised of replacement or repair arrangements and disposition of the equipment. Please include model number, type number and serial number when referring to this instrument for any reason.

WARRANTY

ALFRED ELECTRONICS warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and the replacing of any defective parts. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and which upon our examination is disclosed to our satisfaction to be defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case an estimate will be submitted before the work is started.

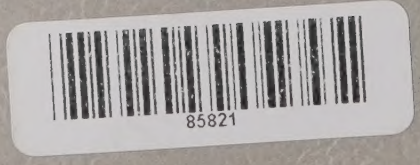
If any fault develops:

1. Notify us, giving full details of the difficulty, including the model number, type number and serial number. Upon receipt of this information you will be sent service instructions or shipping data.

2. Upon receipt of shipping instructions forward the instrument prepaid, and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins when instrument is not covered by this warranty.

PACKING

The instrument should be packed in the original carton. If unusable or not available, use a wooden box with approximately three inches of excelsior or other shock-absorbing material surrounding the instrument. If desired, packing services of a local Transfer and Storage company may be employed.


85821